DAHLGREN DIVISION
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CSS/TR-00/04

MOBILE UNDERWATER DEBRIS SURVEY SYSTEM (MUDSS) FINAL REPORT

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MARCH 2000

REPORT DOCUMENTATION PAGE			*Form Approved* *OBM No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, search existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC.			
1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE March 2000	3. REPORT TYPE AND DATES COVERED	
4. TITLE AND SUBTITLE Mobile Underwater Debris Survey System (MUDSS) Final Report			5. FUNDING NUMBERS
6. AUTHOR(S) P. J. Carroll, J. F. McCormick, J. D. Lathrop, D. C. Summey, D. J. Overway, J. E. Fernandez, J. S. Taylor, C. N. Pham, G. A. Bills, W. S. Howell, P. M. Mount, R. A. Leasko, A.R. Davenport, T. H. Chao, A. Chutjian, and J. Wright			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Attn: R23 Commanding Officer CSS DD NSWC 6703 West Highway 98 Panama City FL 32407-7001			8. PERFORMING ORGANIZATION REPORT NUMBER CSS/TR-00/04
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Strategic Environmental Research and Development Program (SERDP) 901 North Stuart St., Suite 303 Arlington VA_22203			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE A

13. ABSTRACT (Maximum 200 words)

This report documents results of the Mobile Underwater Debris Survey System (MUDSS) Strategic Environmental Research and Development Program (SERDP) project that was conducted in two phases over the period of 1995 through 1998.

MUDSS Phase I included a set of two successful feasibility demonstrations. The feasibility demonstrations included an at-sea demonstration of a multi-sensor MUDSS prototype against unexploded ordnance (UXO) targets in the late summer of 1995, and a demonstration of trace explosive detection in sediment samples taken near underwater UXO in October 1996.

MUDSS Phase II included development and demonstration of an advanced and refined MUDSS survey system using the experience with the MUDSS prototype of Phase I. MUDSS Phase II technology demonstration was held at a former practice-bombing site in November 1998. The MUDSS technology demonstration resulted in a successful mapping of suspected UXO in an environmentally difficult, muddy UXO site.

14. SUBJECT TERMS			15. NUMBER OF PAGES
Mobile Underwater Debris Survey System, Trace Explosive Detection, Underwater UXO Mapping			222
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITYCLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI std. Z39-18
298-102

FOREWORD

The Mobile Underwater Debris Survey System (MUDSS) is a Strategic Environmental Research and Development Program (SERDP) technology demonstration project directed at demonstrating technologies to successfully survey formerly used underwater defense sites (FUDS), for ordnance and explosive waste (OEW). The MUDSS project was executed jointly by the Coastal Systems Station (CSS) of the Naval Surface Warfare Center, Dahlgren Division, and by the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration (NASA). MUDSS heavily leverages acoustic, magnetic, and electro-optic (EO) minehunting sensor and signal and image processing technologies under development at CSS for the Office of Naval Research. It also incorporates signal, image processing, and visualization technologies under development at JPL for NASA, and trace chemical detection technologies under development at JPL for the Federal Aviation Administration.

This report documents results of the MUDSS SERDP project that was conducted in two phases over the period of 1995 through 1998. MUDSS Phase I included a set of two successful feasibility demonstrations. The feasibility demonstrations included:

- An at-sea demonstration of a multi-sensor MUDSS prototype against unexploded ordnance (UXO) targets in St. Andrews Bay (near Panama City, FL) in the late summer of 1995.
- A demonstration of trace explosive detection in sediment samples taken near underwater UXO at Halifax, NS in October 1996.

MUDSS Phase II included development and demonstration of an advanced and refined MUDSS survey system using the experience with the MUDSS prototype of Phase I. MUDSS Phase II technology demonstration was held at a former practice-bombing site in Choctawhatchee Bay (near Eglin AFB, FL) in November 1998. The MUDSS technology demonstration resulted in a successful mapping of suspected UXO in an environmentally difficult, muddy UXO site.

Approved by:

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EXECUTIVE SUMMARY

The Mobile Underwater Debris Survey System (MUDSS) is a Strategic Environmental Research and Development Program (SERDP) technology demonstration project directed at demonstrating technologies to successfully survey underwater sections of formerly used defense sites (FUDS) for ordnance and explosive waste (OEW). The MUDSS project was executed jointly by the Coastal Systems Station (CSS) of the Naval Surface Warfare Center, Dahlgren Division, and by the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration (NASA). MUDSS heavily leverages acoustic, magnetic and electro-optic (EO) minehunting sensor, and signal and image processing technologies under development at CSS for the Office of Naval Research. It also incorporates signal, image processing, and visualization technologies under development at JPL for NASA, and trace chemical detection technologies under development at JPL for the Federal Aviation Administration.

This report documents results of the MUDSS SERDP project that was conducted in two phases over the period of 1995 through 1998. MUDSS Phase I included a set of two successful feasibility demonstrations. Feasibility demonstrations included an at-sea demonstration of a multi-sensor MUDSS prototype against unexploded ordnance (UXO) targets in St. Andrews Bay (near Panama City, FL) in the late summer of 1995, and a demonstration of trace explosive detection in sediment samples taken near underwater UXO at Halifax, NS in October 1996. MUDSS Phase II included development and demonstration of an advanced and refined MUDSS survey system using the experience with the MUDSS prototype of Phase I. MUDSS Phase II technology demonstration was held at a former practice-bombing site in Choctawhatchee Bay (near Eglin AFB, FL) in November 1998. The MUDSS technology demonstration resulted in a successful mapping of suspected UXO in an environmentally difficult, muddy UXO site.

The report provides details of the MUDSS Phase I and Phase II demonstrations with particular emphasis on the Phase II Technical Demonstration (TD) at Choctawhatchee Bay. During the five-day Phase II TD, MUDSS successfully demonstrated the capability of the MUDSS acoustic, magnetic and electro-optic sensor suite to detect, localize and identify 500-lb (227-kg) and 1000-lb (454-kg) bomb test targets in a calibration target set deployed on a sand bottom in 20-25 ft (6.1-7.6 m) deep water. Location of the test targets was measured using differential global positioning (DGPS) equipment and determined to be repeatable within +/- two to three meters. MUDSS then successfully surveyed a two square nautical mile search area where UXO were dropped during WWII practice bombing exercises. MUDSS located and mapped the position of approximately 150 targets with magnetic signatures of a 250-lb (113-kg) to 500-lb (227-kg) bomb. A similar number of targets were detected acoustically. Data fusion techniques showed that a small number of targets (~10) were detected within ten meters by both acoustic and magnetic sensors. A significant number of magnetic targets were buried and thus

could not be detected by acoustic sensors. The electro-optic sensor was generally not useful for target reacquisition and identification during the TD survey since the detected targets were found in heavily silted and muddy bottom areas. MUDSS used Navy divers employing hand-held magnetic sensors to relocate and examine approximately twenty of the detected target sites. The divers relocated several targets including a steel hatch cover, angle iron, and a steel cylinder, but generally had great difficulty relocating targets due to the deep silt bottom [>3 ft (0.9 m)] in much of the survey area. Sediment samples were taken at several suspected UXO locations. Chemical detection tests of the sediment samples were performed by JPL but no samples detected trace explosives.

Several important conclusions are drawn from the MUDSS Choctawhatchee Bay Technical Demonstration. The MUDSS system performed well in a very difficult UXO environment that included very poor visibility and a deep, silty bottom. The flexibility of MUDSS sensor suite was crucial since magnetic detection proved to be the only viable UXO sensing technique in this difficult but not untypical search environment. MUDSS technical demonstration also showed that diver reacquisition and UXO identification is much more difficult than anticipated especially in a silty environment. Improved diver sensors are required to permit clear UXO identification in difficult environmental conditions. Improvements in UXO validation combined with demonstrated MUDSS mapping capability can make MUDSS a viable UW UXO survey system for a wide range of realistic UXO sites.

The data provided in this report is reported initially in either metric or English units according to various equipment readouts used to record the measurement. When English units are used, the metric equivalent will follow in parentheses. Metric numbers are rounded to the nearest significant number of the English counterpart. No English to metric conversion occurs in figures or tables.

INTRODUCTION

MUDSS is a Strategic Environmental Research and Development Program (SERDP) technology demonstration project directed at demonstrating technologies to successfully survey formerly used defense sites (FUDS), located underwater, for ordnance and explosive waste (OEW). The MUDSS project was executed jointly by the Coastal Systems Station (CSS) of the Naval Surface Warfare Center, Dahlgren Division, and by the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration (NASA). MUDSS heavily leverages acoustic, magnetic, and electro-optic (EO) minehunting sensor, and signal and image processing technologies under development at CSS for the Office of Naval Research. It also incorporates signal, image processing, and visualization technologies under development at JPL for NASA, and trace chemical detection technologies under development at JPL for the Federal Aviation Administration.

This report documents results of the MUDSS SERDP project that was conducted in two phases over the period of 1995 through 1998. MUDSS Phase I included a set of two successful feasibility demonstrations. Feasibility demonstrations included an at-sea demonstration of a multi-sensor MUDSS prototype against unexploded ordnance (UXO) targets in St. Andrews Bay (near Panama City, FL) in the late summer of 1995, and a demonstration of trace explosive detection in sediment samples taken near underwater UXO at Halifax, NS in October 1996. MUDSS Phase II included development and demonstration of an advanced and refined MUDSS survey system using the experience with the MUDSS prototype of Phase I. MUDSS Phase II technology demonstration was held at a former practice-bombing site in Choctawhatchee Bay (near Eglin AFB, FL) in November 1998. The MUDSS technology demonstration resulted in a successful mapping of suspected UXO in an environmentally difficult, muddy UXO site.

This report includes discussion of the underwater UXO problem and a description of the MUDSS concept and approach. The focus of the report is on the feasibility tests of 1995 and 1996 and the MUDSS technical demonstration of 1998. Test discussions include test goals, configuration, test design, test execution, analysis and results. The report also provides recommendations for improving MUDSS and transitioning MUDSS into an economic, commercially viable UXO survey system.

BACKGROUND: THE UNDERWATER UXO PROBLEM

It is estimated that there are over fifty formerly used defense sites, installations targeted by the Base Realignment and Closure Act, and active ranges that have significant quantities of UXO. There is currently no satisfactory economical method for surveying these sites to determine the extent of the UXO problem or to locate the ordnance for remediation. There are several reasons why there is no satisfactory underwater survey system.

- Underwater (UW) detection of UXO-sized objects is difficult especially under the widely varying environmental conditions found at UXO sites.
- There are a wide variety of UXO of interest varying in size from small shells to bomb-sized targets.
- UW UXO sites are often highly cluttered with debris that is difficult to distinguish from UXO.
- Over time UXO targets often bury into muddy, silty and sandy bottoms; conventional sonar or electro-optic sensors cannot detect buried targets.

High-resolution commercial sonar can detect UXO that is unburied (or proud) on the bottom, but adverse environmental conditions often limit detection range and quality of the sonar image. Sonar performance is often reduced in shallow water environments due to multi-path behavior and surface reflection. The presence of thermoclines can also create reflections that reduce sonar performance. Commercial electro-optic sensors can provide target images but have very limited ranges and optical sensor performance can be reduced by poor water clarity. Complicating matters further, many underwater UXO sites include soft or muddy bottom areas where UXO bury over time. Sonar and optical sensors have essentially no capability to detect buried targets. Commercial magnetometers can detect buried magnetic targets but provide only ambiguous target location; and target magnetic moment information is insufficient for target discrimination. Detected targets are often ambiguous or buried and require additional inspections by divers using acoustic and/or magnetic ordnance locators. Buried targets must be probed for UXO confirmation. Divers with ordnance locators are prohibitively slow and expensive since UXO sites of interest often cover several square miles or more.

MUDSS APPROACH/CONCEPT

The MUDSS concept is based on combining the capabilities of multiple state-of-the-art sensors and processing, optimized for detection and discrimination of underwater (including buried) targets, combined with visualization and global positioning system (GPS) technologies to generate maps of the location of detected UXO. A conceptual view of MUDSS is shown in Figure 1. A surface craft tows the MUDSS sensors that are housed in two towed vehicles. The first tow vehicle is an active tow body that houses a commercial ahead-looking sonar (SeaBat), a dual frequency high frequency/low frequency (HF/LF) side scan synthetic aperture sonar (SAS), and a laser line scan (LLS) electro-optic identification (EOID) sensor. The magnetic sensor, a superconducting magnetic gradiometer array, is housed in a second passive vehicle that is towed behind the first vehicle. The SeaBat is primarily a collision-avoidance and a target relocation

sensor. The tow bodies also house data transmission electronics that communicate with MUDSS control and display electronics mounted topside in a MilVan/control van on the tow craft

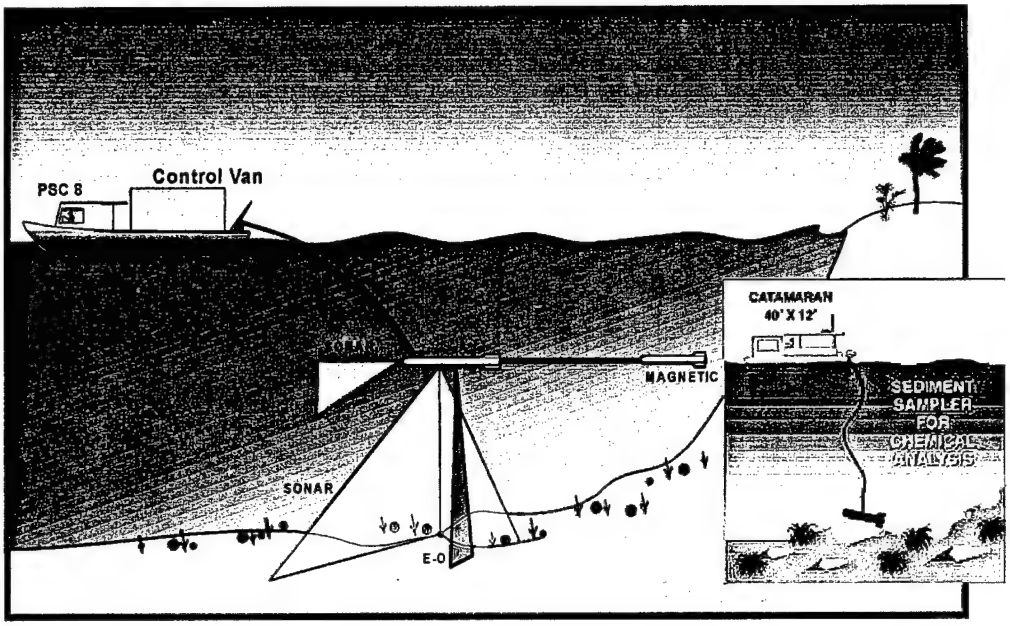

FIGURE 1. THE MUDSS CONCEPT

Not shown in Figure 1 is the antenna for the GPS receiver. The antenna is towed behind the tow craft on a float directly above the first tow body. The GPS receiver is operated in a differential mode to provide accurate target coordinates and permit mapping of the location of targets detected by the MUDSS detection sensors. MUDSS is a highly flexible system that can be operated from different tow craft (catamaran, ocean-going ship, etc.) as required by the search area environment. MUDSS is designed to operate in shallow water from 20-30 ft (6.1-9.1 m) to depths approaching 200 ft (61 m).

Shown in the inset of Figure 1 is a MUDSS sediment sampling capability to be used in cases of buried UXO. Sediment samples are collected near suspected buried UXO objects and the samples are post-analyzed using ultra-high sensitivity chemical sensors that detect trace amounts of explosives. Conceptually, sediment samples can be taken using a separate sample-collecting vehicle. Sediment samples were collected by Navy divers during the MUDSS Phase II Technical Demonstration.

MUDSS operates in a *search* mode and an *identification* mode. In its operational *search* mode MUDSS traces parallel search paths across a search area with the acoustic and magnetic sensors. The MUDSS active towed vehicle is "flown" at a predetermined height above the bottom that is selected to maximize MUDSS sensor detection range. The acoustic and magnetic sensors detect UXO at a specific range for a given size UXO target so that the system "sweeps out" a UXO detection path width as MUDSS is towed. UXO detection and detection criteria for MUDSS sensors are discussed below. GPS position of each detected, potential UXO target is

logged and a target icon is plotted graphically on a map display of the search area. The surface craft traverses a set of parallel tracks offset by a distance equal to (or actually slightly less than) the detection path width for the UXO target of interest, and a map of the detected targets is generated for the search area. Upon completion of detection of the search area, MUDSS transitions to an *identification* mode. In the UXO *identification* mode, MUDSS uses GPS target coordinates to reacquire and confirm detected UXO targets. MUDSS uses the EOID sensor during reacquisition and *identification* mode to obtain a target image for UXO confirmation. Detected UXO targets that are buried cannot be confirmed with the EOID sensor. For buried targets MUDSS relies on the target magnetic characteristics, and uses target magnetic size (magnetic moment) estimates calculated from magnetic sensor data to qualify the target as "UXO-like." Additional confirmation of a buried UXO target is accomplished by chemical detection of trace explosives in sediment sampled from the vicinity of the detected target site. During the MUDSS SERDP program, UXO target detection was confirmed by Navy divers using hand-held sensors (acoustic and/or magnetic) to search and relocate buried targets in the search area. MUDSS operates at tow speeds of four to eight knots. Operating at eight knots MUDSS can achieve a search rate of 0.36 nmi^2/hr against 500-lb (227-kg) bomb-sized targets when operating in a good environment.

MUDSS DESIGN CONSIDERATIONS

The MUDSS concept is based on application of a set of state-of-the-art underwater sensors that permit rapid and positive detection and identification of a range of UXO (bombs, mortar, shells, etc.) in the variety of environmental conditions commonly encountered during underwater UXO surveying. The MUDSS concept acknowledges that there is no one underwater sensor that can detect <u>and</u> identify the complete range of UXO targets of interest in realistic environmental conditions. MUDSS relies on a set of underwater sensors with strengths that can be combined to provide timely UXO mapping capability at a realistic rate and cost.

<u>MUDSS Detection and Identification Sensors</u>

The MUDSS sensor suite includes acoustic, magnetic and electro-optic sensors originally designed and tested as part of the US Navy Magnetic Acoustic Detection of Mines (MADOM) underwater minehunting project. Each sensor was designed to detect underwater objects at maximum range and to provide object "image" characteristics suitable for target identification and discrimination from underwater debris. The MUDSS sensor suite includes sensors capable of detecting proud bottom mines and mines buried in the bottom. Unique signal processing was developed for each MADOM sensor to maximize the sensor performance (detection/image characteristics) while operating towed in an underwater search mode. The MUDSS concept expands on the MADOM sensors, adding updated sensor elements that extend detection range or imaging quality and reconfiguring the sensors to fit in a more compact MUDSS tow body configuration. The MUDSS concept also includes expanded sensor computational processing and display capability to permit real-time detection and identification and to create maps of the detected UXO target locations.

Criteria for underwater object detection and image quality differ from sensor to sensor. Object detection and identification criteria and factors that led to the selection of the MUDSS sensors are discussed below.

The MUDSS primary acoustic sensor is a dual-sided, dual-frequency (20 kHz/180kHz), synthetic aperture sonar (SAS) capable of detecting underwater objects at ranges of forty meters (80-m path) with resolution of 7.5-cm x 7.5-cm for low frequency and 2.5-cm x 2.5-cm at high frequency. Output of the MUDSS acoustic sensors is used to create a two dimensional acoustic picture of the bottom as the tow vehicle moves in the tow direction. MUDSS dual-sided acoustic sensors project on both sides of the tow vehicle. Acoustic reflections from objects on the bottom are displayed as "images" on the acoustic output. Figure 2 shows high frequency and low frequency SAS images from a 1000-lb (454-kg) bomb; the SAS is transmitting/receiving from the right side of each image.

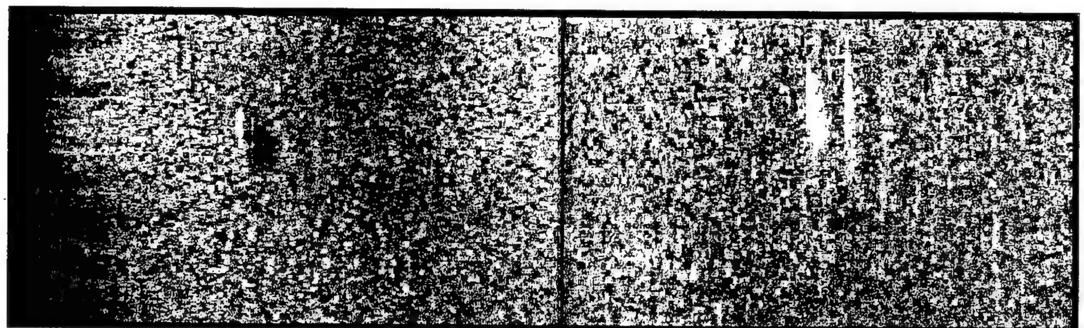

FIGURE 2. HF (LEFT)/LF (RIGHT) SAS IMAGES OF A 1000 LB (454 KG) BOMB

The UXO images are characterized by bright spot reflections from the surface of each UXO and a shadow area, known as a holiday, [on right side of 1000-lb (454-kg) bomb] where the acoustic signal does not reflect back to the acoustic transmitter/receiver. The synthetic aperture technique artificially "creates" a larger aperture sonar by using side scan sonar data over time and compensating for sensor motion to produce very high resolution images. High resolution is a key capability that permits accurate assessment of the detected object size and shape. Object highlights, shadow, size, and shape are the key factors used by sonar operators to identify UXO and distinguish UXO from other underwater debris. UXO sonar operators look for images of man-made objects of cylindrical shape and size to be a bomb or a shell. The MUDSS acoustic sensor also includes a low frequency SAS function to aid in buried target detection. The 20-kHz low frequency SAS signals can penetrate into the sea bottom up to one or two feet and reflect signals from buried objects.

The MUDSS magnetic sensor is a multi-element superconducting magnetic gradiometer sensor that detects the anomalous magnetic field gradient signals of magnetic UXO targets. The majority of UXO have a significant magnetic signal. Magnetic UXO targets generate magnetic fields and magnetic field gradients that are well modeled as a magnetic dipole source. MUDSS uses this unique magnetic sensor to measure selected magnetic field gradients from underwater targets as the sensor is towed through the search area. The target gradient measurements are processed using a CSS-developed algorithm to calculate the target *position* vector relative to the sensor and the *magnetic moment* vector of the target. The magnetic moment vector magnitude is a measure of the magnetic size of the target and the vector direction is an indication of the target

shape and orientation. The magnetic size and orientation are used to discriminate between real UXO targets and underwater debris. The detection range of the MUDSS magnetic sensor varies directly with the target magnetic moment and inversely to the fourth power of the range from the sensor. For 500-lb (227-kg) bomb targets the detection range is of the order of 50 ft (15 m), so the width of the detection path for the MUDSS magnetic sensor is approximately 100 ft (30 m).

A particularly important feature of the MUDSS magnetic sensor is that it detects buried as well as proud targets. The sea bottom interface does not affect the very low frequency magnetic fields and gradients from the targets. Since many underwater UXO search areas are conducive to target burial, the MUDSS magnetic sensor provides a critical detection capability beyond that provided by acoustic or optical sensors. Figure 3 shows a plot of five independent magnetic field gradients from a 1000-lb (454-kg) bomb as measured by a five-element gradiometer as it is towed past the target.

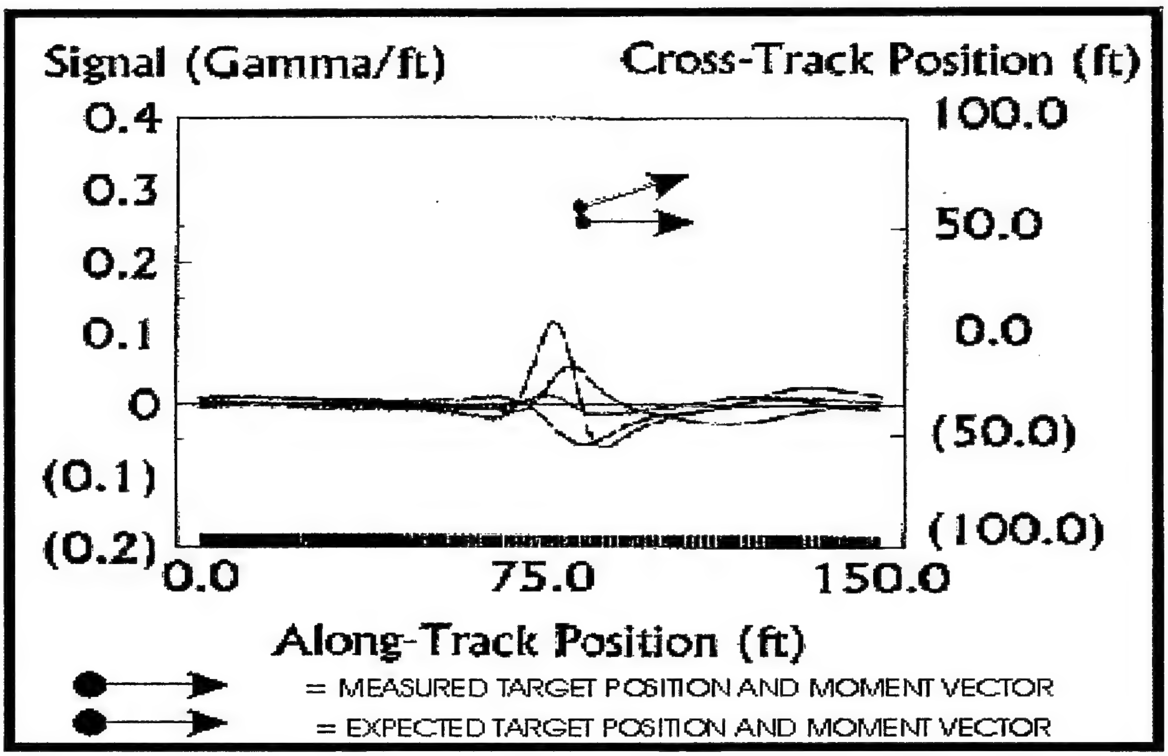

FIGURE 3. MAGNETIC GRADIENT SIGNALS FROM A 1000-LB (454-KG) BOMB AND COMPARISON OF CALCULATED POSITION AND MAGNETIC MOMENT VERSUS REAL POSITION AND MOMENT

The position and magnetic moment vector of the target is shown with the target approximately 50 ft (15 m) to the side of the track. Also shown is the target position and moment vector as calculated from the measured target gradients using a CSS-developed Vaizer-Lathrop algorithm. The calculated target position and moment vector are in good agreement with the real target values.

While MUDSS acoustic and magnetic sensors provide the primary search capability, the MUDSS electro-optic Laser Line Scan (LLS) sensor can provide vital optical imaging capability to confirm UXO targets which are proud on the bottom. The MUDSS LLS employs scanning techniques that reduce the effects of light backscatter and produce quality images at exceptional ranges several times farther than conventional underwater cameras. The MUDSS LLS is a Raytheon-developed sensor operating a blue-green laser at 532-nm and providing resolution of ¼-in x ¼-in (0.64 x 0.64 cm) at ranges of up to five to seven attenuation lengths. Figure 4 shows an example of an electro-optic image of a test bomb taken with the LLS during Navy Combined Joint Task Force Exercise 96 (CJTFEX 96). During the CJTFEX tests the LLS was towed at approximately 100-foot (30.4-km) depths and the image in Figure 4 was taken with the LLS
6.5 m above the bottom.

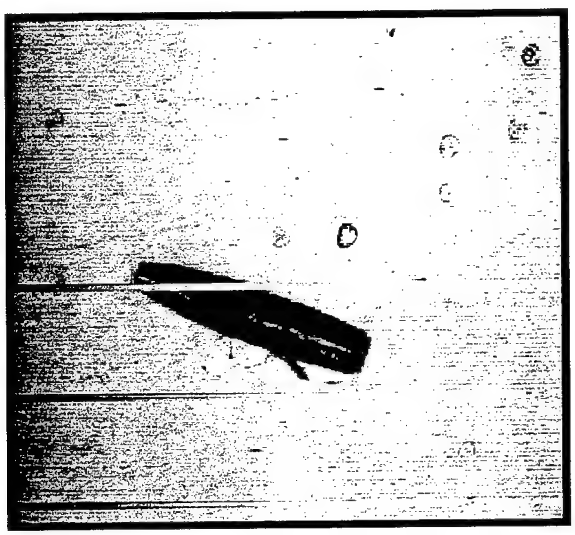

FIGURE 4. EOID IMAGE OF TEST BOMB USING LLS OPERATING 6.5 METERS ABOVE THE BOTTOM

MUDSS System Requirements

The MUDSS towed vehicle system is required to provide smooth translation motion during the search operation to maximize acoustic and magnetic sensor performance. The lead MUDSS towed vehicle (towed body 1) is designed with an active depressor to provide controlled towing of the MUDSS towed body and sensors at a selected distance above the bottom. The tow vehicle height above the sea bottom is selected to maximize the MUDSS effective search width of the acoustic and magnetic sensors for the search phase and the LLS during the MUDSS reacquisition and identification phase. The MUDSS towed vehicle is typically operated ten to fifteen feet above the bottom to maximize the MUDSS sensor search widths. The lead MUDSS towed vehicle is designed to provide smooth towed operation with motion of less than +/- one degree roll, pitch and yaw in Sea State 3.

The MUDSS towed vehicles are designed to provide for stable operation at four to eight knots. The towed vehicle speed is determined by operational requirements of the electro-optic sensor. Four knots is the maximum tow speed for LLS operation at maximum resolution [¼-in x ¼ in or 0.64 x 0.64 cm]. Operation at greater speed produces reduced resolution.

The MUDSS magnetic sensor is operated in a neutrally buoyant, non-magnetic body (towed body 2) towed 75 ft (23 m) behind the active depressor towed body. The magnetic sensor is operated remotely from the active depressor and from the surface tow craft to reduce the magnetic field and gradient noise near the magnetic sensor. Magnetic noise from MUDSS equipment can reduce the effective detection range of the magnetic sensor that, in turn, reduces the magnetic sensor search path width and the MUDSS UXO detection rate.

<u>MUDSS Computation and Data Transfer Requirements</u>. MUDSS is designed to incorporate computers in the towed vehicles that provide capability to collect data, to process selected sensor data, and to transfer both processed and raw data to the topside electronics onboard the tow craft for additional processing, sorting, display and recording.

<u>MUDSS Display and Visualization Requirements.</u> MUDSS is designed to include multiple displays to permit assessment of system operational factors, monitor the status of the towed vehicles, monitor individual sensor outputs at several different stages of processing, tag each detected target, fuse data from independent sensors, and display target locations on map of the search area. Display and visualization electronics are housed in a MilVan on the tow craft.

MUDSS is designed as a flexible system that can be configured to meet the needs of the search area. The MUDSS system is designed to be operable from several different tow craft. MUDSS was configured for operation from a catamaran during the MUDSS feasibility demonstration tests. The catamaran provided a stable, low magnetic tow platform for use in calm waters. During the technology demonstration MUDSS was configured for towed operation from a surface craft that was more suitable for open sea operation. MUDSS did not require the surface craft for the technology demonstration in Choctawhatchee Bay but the sensor system had been operated from a surface craft during other Navy operations just prior to the tech demo and the decision was made to continue operation from the surface craft.

THE MUDSS PROGRAM

The MUDSS program was conducted over a four-year period in two phases. Phase I included two tests in 1995 and 1996 to demonstrate the feasibility of the MUDSS sensors to detect and identify underwater UXO. The Feasibility Demonstration (FD) Test conducted in August 1995 was centered on demonstrating the capability and interoperation of the prime MUDSS detection sensors in a towed underwater mode. Sensors that were tested included side scan sonar, a superconducting magnetic gradiometer array and an optical laser line scan sensor. This FD test was conducted using available Navy sensors that had been developed for minehunting. The sensors were not in their final MUDSS form or configuration, and the detection and image processing were not performed in real-time. The objective of the feasibility tests was to demonstrate that the sensors could be used to detect a range of UXO and that MUDSS system requirements (e.g., towing stability, search pattern system navigation control, target reacquisition) could be met in a more mature MUDSS system design. The feasibility test conducted in October 1996 at Halifax was to demonstrate trace explosive sampling techniques could be used to detect underwater UXO. Soil samples were taken from locations near WWII bombs in Halifax Harbor and analyzed using JPL high sensitivity trace chemical analysis techniques to determine if explosives could be detected from real UW UXO and used as a reliable method of confirming UXO. This independent method of confirming UXO is envisioned as a vital part of the MUDSS concept to be used when detected UXO targets are buried and cannot be confirmed by EOID images.

Phase II of the MUDSS program included upgrading of the Phase I MUDSS sensors and system components to final configuration to permit real-time UXO target detection and identification. Phase II culminated in November 1998 with a MUDSS Technology Demonstration (TD) at a real UXO site near Eglin AFB, FL. The MUDSS TD objective was to search a two square mile area of Choctawhatchee Bay, FL used as a World War II practice-bombing site and to map the location of suspected 250-lb (113-kg) and 500-lb (227-kg) UXO. The development of several key sensor and system components of the MUDSS technology demonstration system was supported independently by US Navy R&D programs sponsored by ONR. Key MUDSS components that were developed under continuing ONR mine hunting programs included the upgraded and reconfigured HF/LF SAS and EOID sensors, the active depressor used as the MUDSS lead tow body, and high speed data transfer electronics required for real-time image processing and presentation. These upgraded sensors and equipment were shared between ONR programs and MUDSS and were also used on several Navy tests during the MUDSS Phase II development period. Navy tests included Maritime Combined Operations Training (MARCOT) in 1998, and the acoustic and EOID sensors and towed vehicle One were deployed as part of the Swiss Air Recovery effort off Nova Scotia in Fall 1998.

PHASE I: 1995 ST. ANDREWS BAY FEASIBILITY DEMONSTRATION TEST

Phase I of the MUDSS project tested the feasibility of the MUDSS concept by operating several sensors from the same tow vehicle and surveying a field of UXO targets laid in St. Andrews Bay, Panama City Florida.

The goal of the Phase I Feasibility Demonstration (FD) was to demonstrate that the performance of a prototype MUDSS sensor suite consisting of on-hand acoustic, magnetic and EO sensors shows good promise for detecting and identifying UXO targets. Feasibility demonstration results were subsequently used to guide development of upgraded sensors for the MUDSS technology demonstration.

MUDSS FEASIBILITY DEMONSTRATION CONFIGURATION

A conceptual view of the MUDSS FD system is shown in Figure 5. The surface craft is a custom designed magnetically and acoustically quiet, shallow draft trailerable catamaran. The sonar in Figure 5 are SEA-BAT, HPSS, and SAS. The electro-optic (EO) sensor is listed as LLS and the magnetic sensor is the gradiometer.

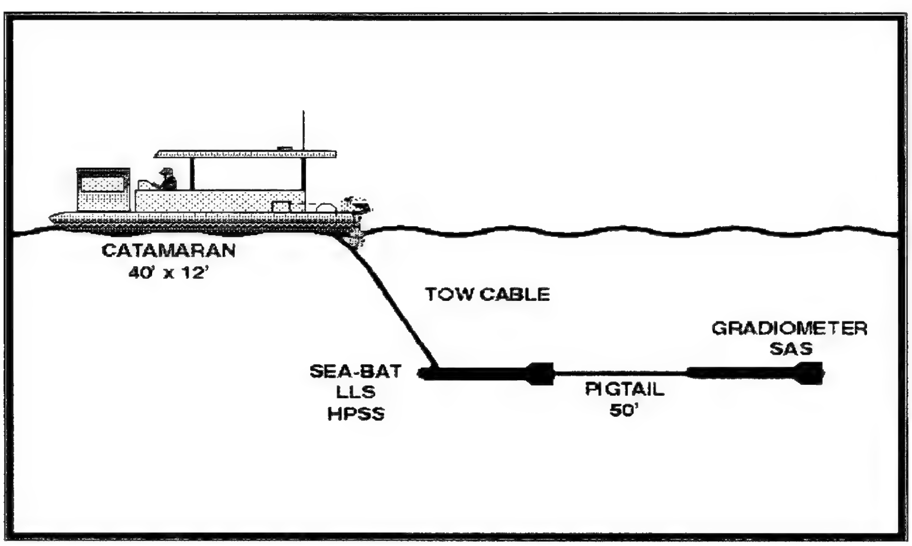

FIGURE 5. MUDSS FEASIBILITY DEMONSTRATION SYSTEM CONFIGURATION

In the MUDSS FD system configuration, the dead-weight depressor (see Figures 6 and 7) is suspended off of the back of the catamaran. The dead-weight depressor houses the following sensors:

1. A commercial ahead-looking sonar unit, the RESON SeaBat.
2. CSS-developed high frequency side scan sonar (high performance sidescan sonar [HPSS])
3. A laser line scanner (Model LS 4096) leased from Raytheon Corporation (the LLS is actually rigidly mounted below the dead weight depressor)

A neutrally buoyant second vehicle is towed as a pigtail behind the dead-weight depressor (see Figure 7). The neutrally buoyant towed vehicle houses the following sensors:

1. A CSS/Northrop/Grumman-developed, low frequency synthetic aperture sonar (SAS)
2. A CSS/Unisys-developed superconducting gradiometer/magnetometer sensor (SGMS)

The dead-weight depressor is suspended by the tow cable from a winch on the catamaran that controls the operating depth of the towed system. The cabin on board the catamaran provides space for an acoustics operator, a magnetic operator, an EO operator, a GPS operator, and the sensor control and data acquisition systems. The cabin and the catamaran's ten kW generator are placed near the front of the catamaran in order to maximize the distance from these two strongly magnetic objects to the gradiometer towed on the neutrally buoyant vehicle. Only sensor performance was monitored on the catamaran. Sonar and EO images were processed on shore, after testing. Magnetic target positions were also calculated after testing.

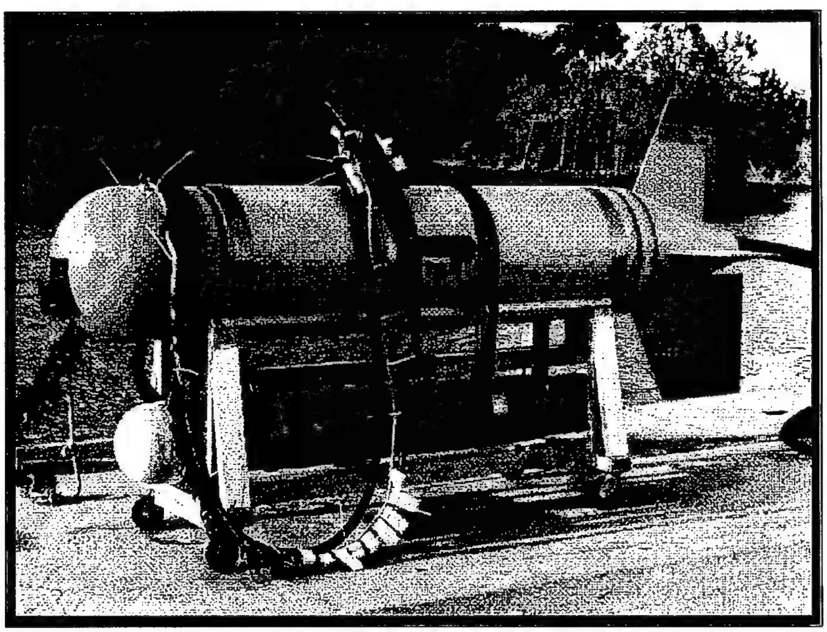

FIGURE 6. DEAD WEIGHT DEPRESSOR

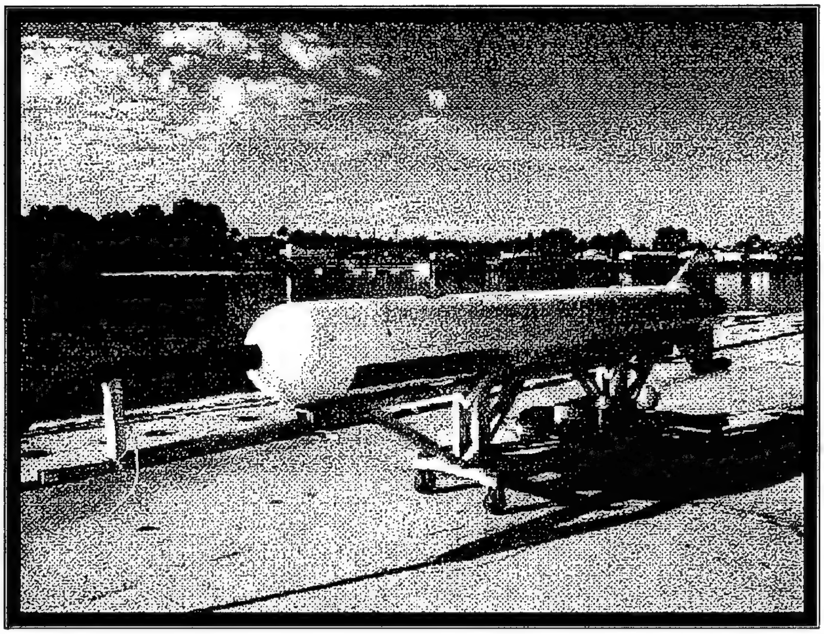

FIGURE 7. NEUTRALLY BUOYANT VEHICLE

The acoustic and magnetic sensors have long ranges and are used for searching for targets. The EO sensor has much shorter range and is used for identifying targets. Searching characteristics of these sensors are listed in Table 1.

TABLE 1. SENSOR CHARACTERISTICS

Sensor	Approximate Range	Search Type
MADOM SAS	0.6-35 m @ 5 knots	sonar, area search
HPSS	4-35 m @ 5 knot	sonar, area search
SeaBat	5-200 m @ 7 knots	sonar, area search
LLS	4-7 m (for 3-5 m sensor altitude from sea bottom)	visible light, target identification
SGMS	22-25 m (dependent on magnetic moment of target	magnetic, area search

Physical characteristic and performance specifications for the acoustic sensors are listed in Appendix A. Physical characteristic and performance specifications for the EO sensor are listed in Appendix B. Physical characteristic and performance specifications for the magnetic sensor are listed in Appendix C.

FD TEST DESIGN GOALS

The MUDSS Phase I Feasibility Demonstration goal was to establish that a set of MUDSS-type sensors could be operated in a multi-sensor towed configuration and successfully detect and identify a variety of representative UW UXO. The MUDSS FD system was

configured using available sensors and towed vehicles. Specific goals for the feasibility demonstration included:

- Operation of existing MUDSS-type sensors together as a single towed package demonstration of UXO target detection and classification.
- Collection of sensor data for a known test target field that included a variety of UXO targets (shells to large bombs) located proud on the sea bottom.
- Post processing of sensor data on shore to confirm target detection with acoustic, EO and magnetic sensors.
- Demonstration that the performance of a prototype MUDSS sensor suite shows good promise against UXO targets and is well characterized by sensor performance models already in place at CSS. Performance models to be used to guide design of upgraded SAS and EOID sensors for MUDSS technology demonstration.

FD TEST AREA AND TARGET FIELDS

The MUDSS FD test was conducted in August 1995 at St. Andrews Bay, near Coastal Systems Station and Panama City FL in the area shown in Figure 8. Water depth at the test area was 30 ft (9.1 m).

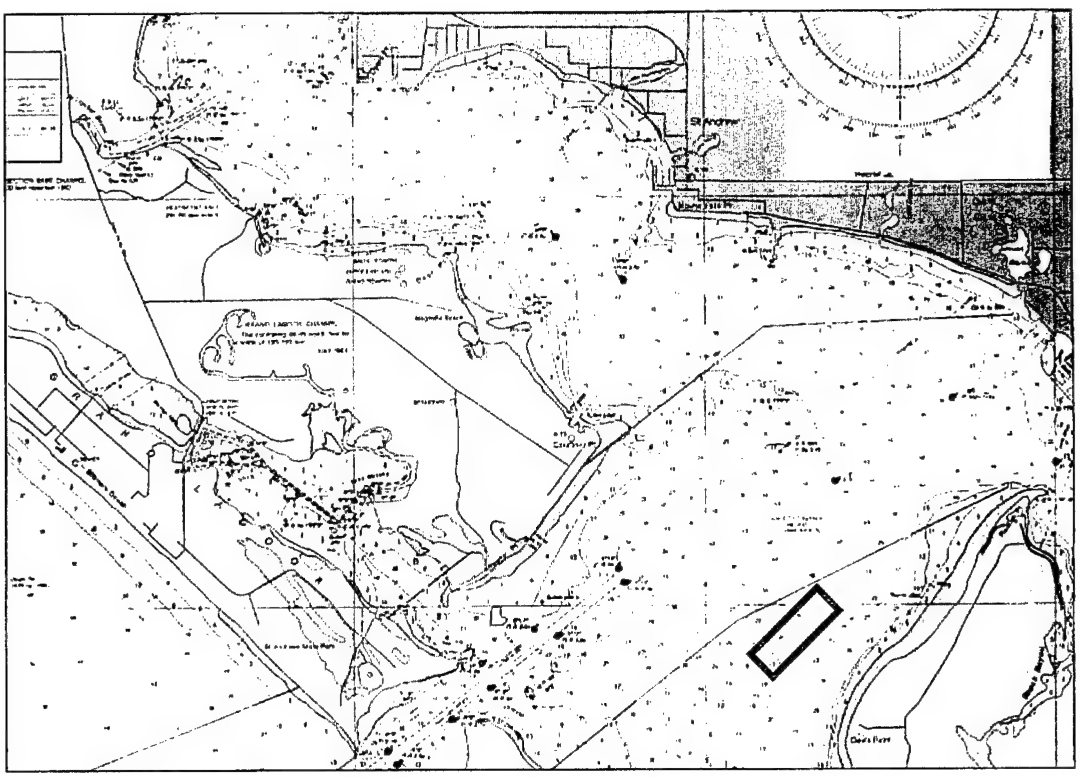

FIGURE 8. ST ANDREWS BAY MUDSS FD TEST AREA

The FD test area contained two target fields each including approximately a dozen UXO targets. The UXO targets in each of these fields spanned the full range of UXO target

sizes. The targets were arranged into two test fields, one designated the clumped field and the second designated the linear field. No significant clutter was noted in the test field area, but after a few days some crabs were seen clustering around the larger bombs in the target field.

The purpose of the clumped field was to provide a high density of targets for efficient data collection by the acoustic and EO sensors. The clumped field consisted of two concentric circles of targets with inner and outer radii of 10-ft (3-m) and 35-ft (11-m), respectively, each circle having six targets (see Figure 9). The clumped layout field contained the following target types:

60-mm Mortar
81-mm Mortar
105-mm Mortar
105-mm Howitzer
106-mm Heat (Projectile w/ Fins)
175-mm [60 in (152 cm), 150#]
200-mm Projectile, 8-in (20-cm), 150-lb (68-kg)
Mk 82 Bomb, 500-lb (227-kg)
Mk 83 Bomb, 1000-lb (454-kg)
Mk 84 Bomb, 2000-lb (908-kg)
55-Gallon (208-l) Drum

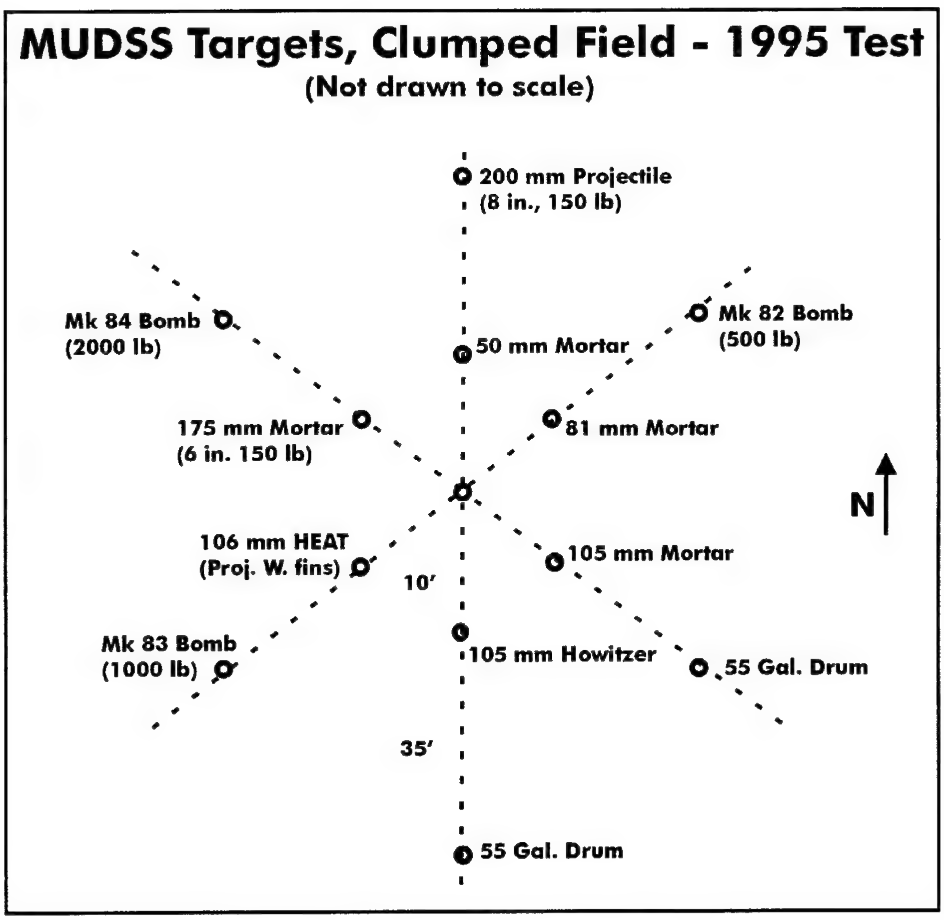

FIGURE 9. PHASE I CLUMPED FIELD

Because the gradiometer cannot distinguish targets that are closely spaced, a second target field, designated the linear field, was also deployed. The linear field consisted of a 663-ft (202 m) long row of small and medium-sized targets running north-south, a second shorter row of three targets (two oil drums and a Mk 82 bomb) parallel to and 30 ft (9.1 m) east of the first row, with a third parallel row of two targets (Mk 83 and Mk 84 bombs) 30 ft east of the second row (see Figure 10). The linear field contained the following UXO type targets:

60-mm Mortar
Long 60-mm Mortar
105-mm Howitzer
105-mm Mortar
175-mm Mortar
203-mm Mortar
Mk 82 Bomb, 500-lb (227-kg)
Mk 83 Bomb, 1000-lb (454-kg)
Mk 84 Bomb, 2000-lb (908-kg)
55-Gal (208-L) Oil Drum

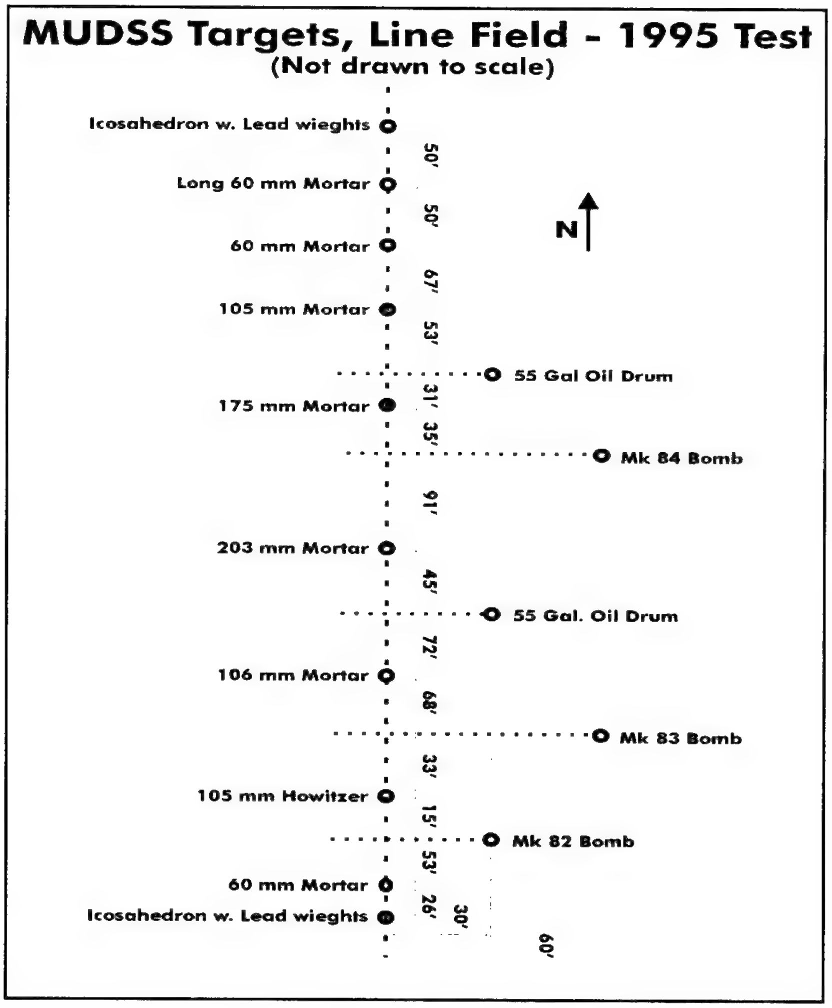

FIGURE 10. PHASE I LINE FIELD

For ease of interpretation of sonar images, which depend strongly on target aspect, the targets in both fields were placed so that the axis of symmetry of each target pointed north.

FD TEST EXECUTION AND DATA ANALYSIS

Over 150 test runs were conducted against the target fields during the FD with various combinations of sensors functioning, including over thirty runs with all sensors functioning simultaneously. The feasibility demonstration sensors operated well against these targets and performed close to expectations. The SeaBat display was videotaped and used primarily for target location for the boat operator towing over the test fields. HPSS and SAS sonar images were processed after the test runs were completed. The unprocessed data output of the sonar (HPSS and MADOM SAS) and the gradiometer (SGMS) was monitored during the runs. All raw sensor data were recorded for later post-processing.

The relatively small portion of the HPSS and SAS data containing targets of interest was beamformed and motion compensated off line to produce digital sonar images. The sonar images were archived for each run on 4-mm digital data tape along with corresponding LS4096 digital EO images, raw gradiometer digital data (including magnetometer channel data for motion compensation) and DGPS data. This data, together with copies of the SeaBat video data, were used to develop automated processing, sensor fusion, and visualization capabilities for later MUDSS technology demonstration tests.

In addition to the sensor and DGPS data, environmental data were also collected during the feasibility demonstration. The data were collected from a small boat anchored a few hundred feet from the clumped target field, and included sound velocity profile and optical attenuation and scattering profiles at 512-nm, the operating wavelength of the LLS.

The water depth in the test area was approximately nine to ten meters deep. The sound velocity profile (from bottom to surface) in St. Andrews Bay was relatively constant during testing, with no large gradients in sound velocity that would limit sonar range. The attenuation coefficient (water clarity measurement for the EO sensor) in St. Andrews Bay was moderately low ranging from 0.5 to 1.2 m^{-1}. This reduced target visibility somewhat, but did not prevent target identification with the sensor towed only a few meters above the target. The performance of the SGMS magnetic sensor is not affected by the water quality of the environment.

FD ACOUSTIC RESULTS

The MADOM SAS, HPSS, and SeaBat images from a selected run (Run 44), even with no accompanying analysis, provide an excellent qualitative summary of the relative merits and capabilities of the three feasibility demonstration sonar. They are shown in Figures 11 and 12. Excellent target size and shape information is evident in these figures. (In the MADOM SAS and HPSS images shown in these figures, the sonar motion was from right to left at the bottom of the figures. The nearest recorded range was 2.0 m, the farthest range was 35 m, and the operating height was between 3.0 m and 4.5 m.).

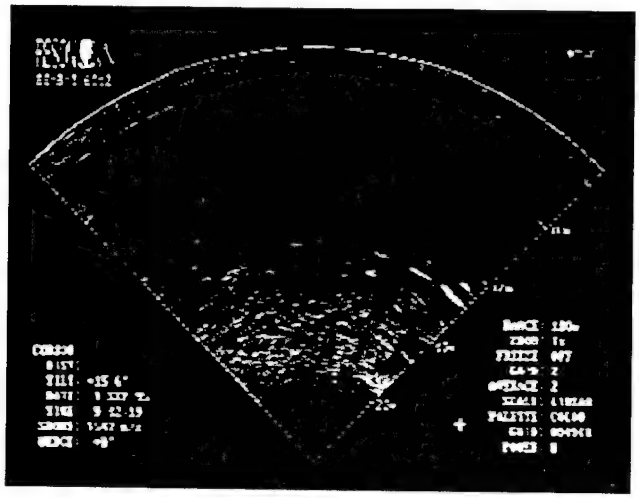

FIGURE 11. SEABAT IMAGE OF RUN 44.

In Figure 12, the clumped field appears to starboard at a range of between 30 m and 50 m. The larger targets in the outer ring can be discerned above the general clutter (multi-pathing obscures the clutter at ranges greater than about 50 m), with the 1000-lb (454-kg) and 2000-lb (908-kg) bomb images showing up prominently. The targets in the inner ring are not discernable above the general clutter. Additional acoustic analysis of FD sonar data was performed to show that the sonar performance prediction model known as Shallow Water Acoustics Toolset (SWAT) can predict the performance of the feasibility demonstration sonar against the test target fields. SWAT was developed at CSS to predict imaging sonar performance against sea mines, operating in the difficult shallow water environment. Validation of SWAT for the Phase I sonar data enabled the MUDSS project to proceed with confidence to performance predictions for future sonar design tradeoffs for the MUDSS TD system. Two primary measures of effectiveness of the SWAT model were tested during the feasibility demonstration: (1) fidelity of the predicted target images and (2) fidelity of the predicted intensities of the general background returns (known as "reverberation") and signal-to-noise ratios (SNRs). For illustrative purposes, reverberation/SNR and target image analyses are presented for a single selected run (Run 44) over the clumped field. Run 44 was chosen because the closest point of approach to the center of the clumped field during this run put the entire field within the range of the HPSS and MADOM SAS, and because the targets are presented at a representative aspect (roughly 45 degrees).

In the top part of Figure 12, the MADOM SAS image of the clumped field for Run 44 shows outstanding target size and shape information. The object visible in the center of the small ring of targets is a screw anchor used by divers for positioning the targets. "Ghost" images from the first multi-path (sonar to target to water surface to sonar) can be seen for the brighter targets at the longer ranges. In the bottom part of Figure 8 is the HPSS image of the clumped field for Run 44. Because of the HPSS narrow vertical beam (13 degrees) and small depression angle (10 degrees), the first returns from the bottom came at a range of twelve to thirteen meters. The direct returns from the targets are relatively weak because of the high operating frequency (600 kHz) of the HPSS, but the shadows provide good shape information for a few of the targets.

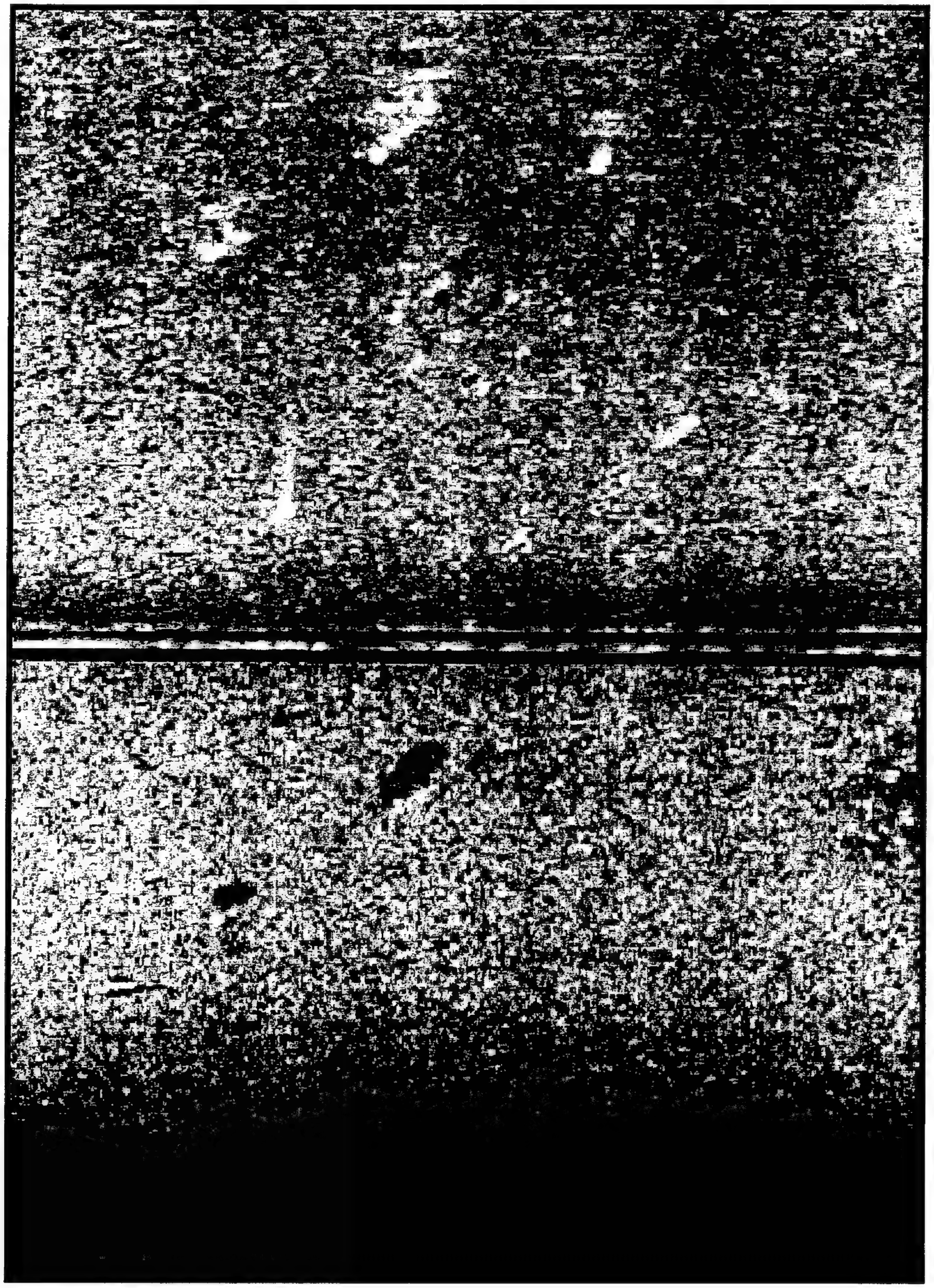

FIGURE 12. RUN 44, MADOM SAS (TOP), HPSS (BOTTOM)

Figure 13 is a comparison among two actual, MADOM SAS, Run 44 images (the 1000-lb (454-kg) bomb and 203-mm howitzer shell) and the corresponding images simulated by SWAT for the MADOM SAS, and the corresponding images simulated by SWAT for a high quality 100-kHz commercial sidescan sonar. Figure 13 illustrates the application of SWAT both as a performance analysis tool and as a performance prediction tool. Units for Figure 13 are in feet.

The top images in Figure 13 from the SAS show sharp and detailed highlights from both targets. The middle images simulated by SWAT show high fidelity agreement between the predicted and actual images. The lower images are corresponding images simulated by SWAT for a high quality commercial 100-kHz commercial sidescan sonar. The SAS target images are clearly superior to the predicted side scan images.

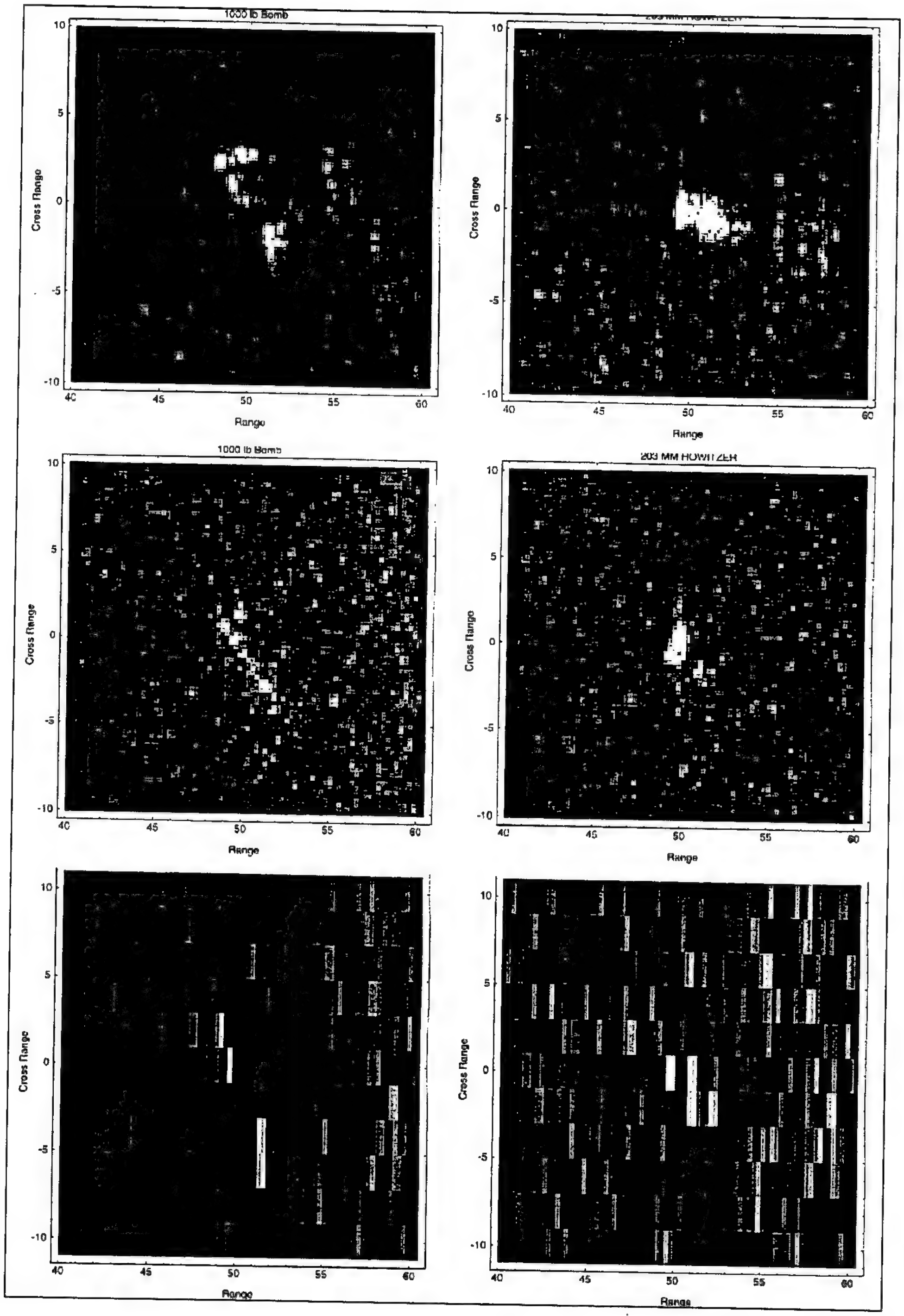

FIGURE 13. RUN 44 TARGETS AND SIMULATIONS

It is evident that the performance of the MADOM SAS against these targets was clearly far superior to the performance of the HPSS and the SeaBat, with the exception of the shadowing, which is almost non-existent in the MADOM SAS images and strong in the HPSS and SeaBat images. The correct modeling of these performance features requires correct modeling of target strengths and of reverberation (including multi-pathing).

Figures 14 and 15 illustrate the fidelity of SWAT in modeling target strengths and reverberation, respectively.

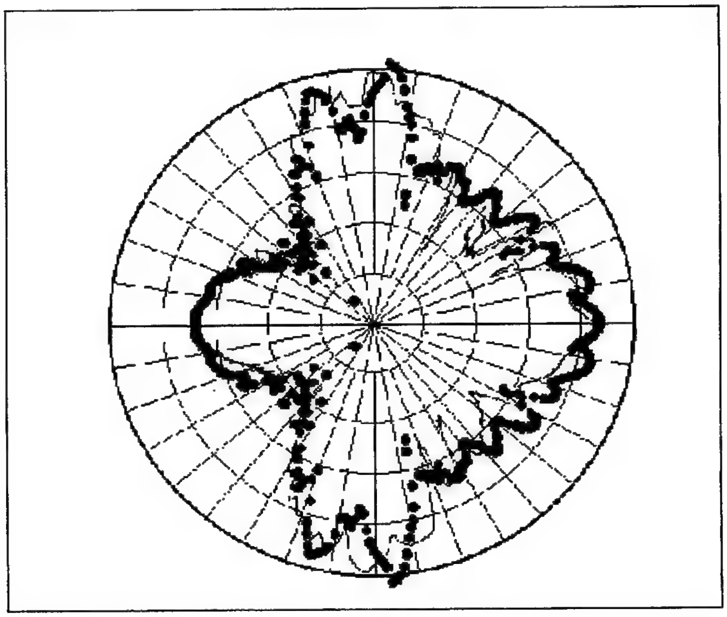

FIGURE 14. TARGET STRENGTH MEASUREMENTS (DOTS) AND SWAT PREDICTIONS (DASHED LINE) FOR A 203-MM HOWITZER SHELL AT 20 KHZ

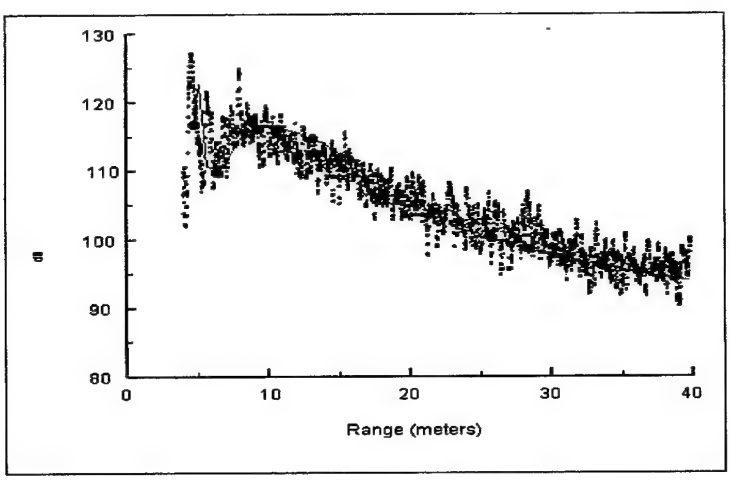

FIGURE 15. PREDICTED (CIRCLES) VERSES MEASURED (DOTS) TOTAL REVERBERATION FOR THE MADOM SAS

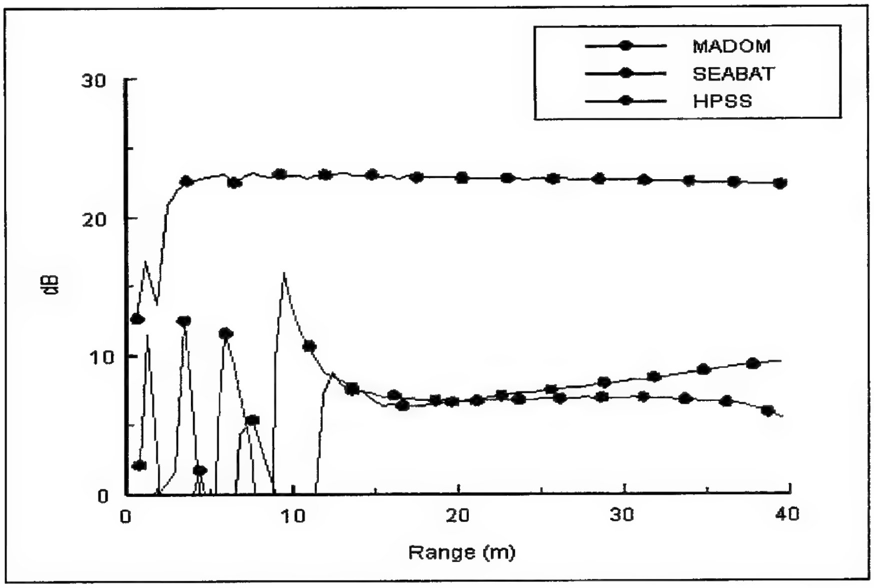

FIGURE 16. SWAT PREDICTIONS FOR THE ASPECT AVERAGED SNR FOR THE SEABAT, MADOM SAS, AND HPSS AGAINST A 203 HOWIZTER SHELL FOR RUN 44 CONDITIONS.

HPSS images are superior to the SeaBat images because of the HPSS higher azimuthal resolution. The shadowing seen with these two sonars is comparable in depth, essentially because their operating frequencies, vertical beamwidths, and depression angles are comparable. The shadow depth is deeper for the HPSS and SeaBat than for the MADOM SAS because their vertical beams are narrower (thus reducing multi-pathing) and because reverberation off the sea surface is a decreasing function of frequency. SWAT predictions for the shadow depths in Run 44 of these three sonars are shown in Figure 13.

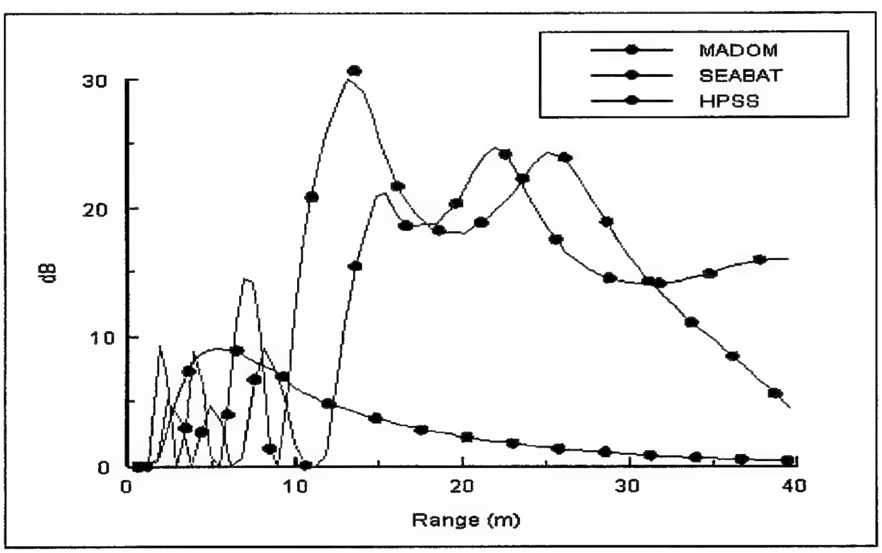

FIGURE 17. SWAT PREDICTIONS FOR THE SHADOW DEPTH OF THE SEABAT, MADOM SAS AND HPSS FOR RUN 44 CONDITIONS.

FD MAGNETICS RESULTS

The magnetic gradiometer sensor tested during the MUDSS feasibility demonstration has two principal advantages over simpler, more common magnetic field sensors such as total field magnetometers. First, it has the highest known sensitivity of any field-deployable magnetic sensor providing it with excellent range [over 50 m against a 2000-lb (908 kg) bomb]. Secondly, its five channels measure all of the independent components of the gradient of the magnetic field, providing sufficient information to localize simultaneously on as many as three targets. By comparison, a total field magnetometer has only one channel and cannot unambiguously localize on even a single target.

The MUDSS magnetic sensor data can be processed to determine both the target position with respect to the sensor and the magnetic moment vector of the target. This magnetic classification information can then be used in conjunction with the sonar images to help correctly classify UXO targets and sort them from the surrounding debris.

Figure 18 shows a portion of the gradiometer time series data from the magnetic sensor for one of the FD tracks near a 1000-lb (454 kg) bomb. The magnetic data includes the five gradiometer signals from a 150-ft (45.7 m) long pass near the 1000-lb (454 kg) bomb in the linear target field. The signals are due principally to the bomb, although other targets in the field are contributing, as is evident in the tails of the signals. The measured and expected (actual) target location and magnetic moment are also displayed. The expected direction of the moment vector is determined from knowledge of the orientation and shape of the target, whose moment is mainly induced. The Vaizer-Lathrop algorithms used for target localization and moment calculation were developed at CSS. It should be noted that the localization algorithms have been refined to reduce clutter since the initial data analysis for the feasibility demonstration.

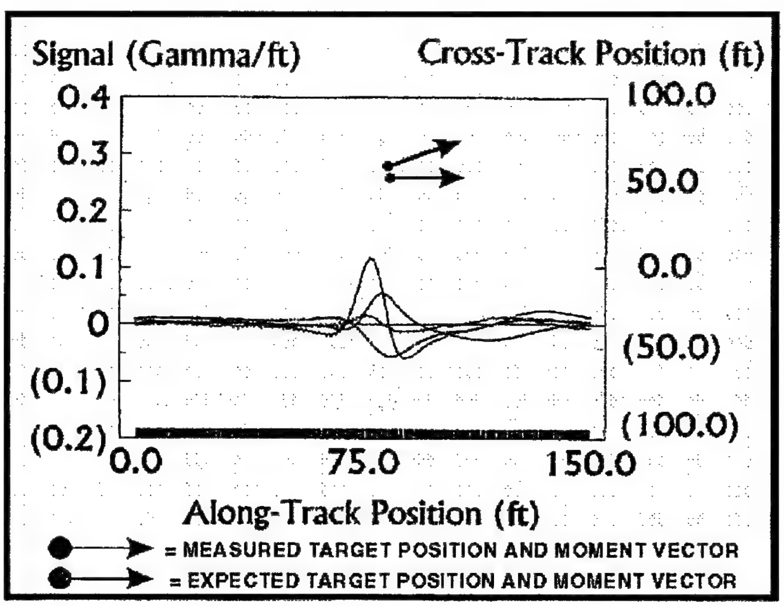

FIGURE 18 GRADIOMETER TIME SERIES DATA

An automatic real-time localization algorithm operates on signals such as these to determine the locations and magnetic moments of the targets contributing to the signals. In Figure 19, this algorithm finds a target having the magnetic moment of a 1000-lb (454 kg) bomb located fifteen meters to port and five meters below the gradiometer, very close to the known location of the actual bomb. Figure 19 shows the locations of the magnetic targets found by the gradiometer in a pass over one of the target fields (the gradiometer trajectory as inferred from the GPS data can be seen in the figure). The size of the dot at each target location is in proportion to the size of the magnetic moment found for the target, illustrating the capability of the gradiometer to distinguish between large and small targets.

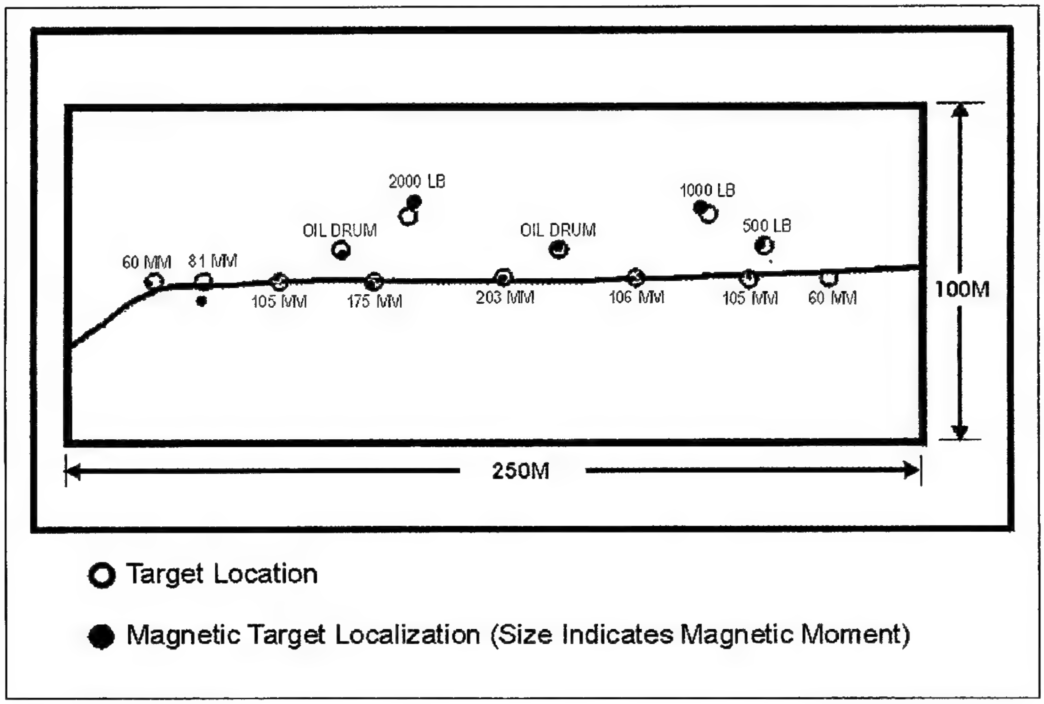

FIGURE 19. GRADIOMETER TARGETS FOUND

Figure 19 shows gradiometer targets (black circles) found in Run 118 over the linear field. The size of each black circle is proportional to the size of the target moment. The open circles are the actual target locations. It is evident from Figure 19 that most of the targets in the linear field, whose actual positions are marked with open circles, have been found by the gradiometer with the exception of the 60-mm mortar.

FD ELECTRO-OPTICS RESULTS

The LLS, LS 4096, operating at 532-nm uses a laser and photo-multiplier receiver synchronously scanned on successive pixels to develop images of the bottom. LS 4096 has a 70-degree field of view and provides high-resolution pixels [0.25-in (0.64 cm) at four knots]. Laser line scan techniques reduce backscatter and glow/forward scatter compared to standard passive cameras.

Examples of LS4096 images for the smallest and largest of the feasibility targets are shown in Figures 20 and 21. Because a laser line scanner casts no shadows, the targets often appear peculiarly flattened, especially if the scattering from them is accurately Lambertian (see Figure 21). Figure 20 shows a 60-mm mortar at a range of five meters (3.5 attenuation lengths). Figure 21 shows a 2000-lb (908 kg) bomb at a range of four meters (3 attenuation lengths)

Additional analysis of FD electro-optic data was performed to show that the target images produced by the LS4096 during the FD can be accurately simulated by IMPERSonator (Imaging PERformance Simulation), the CSS simulator for underwater imaging systems. IMPERSonator simulates propagation of light through the transmission optics (if any) of the underwater imaging system. This simulation includes forward and backward absorption and scattering of light (ambient as well as any active source light) as it travels through the water toward the target, scattering of light from the target (modeled as a Lambertian scatterer), absorption and scattering of light traveling to the receiver, propagation of light through the receiver optics, and conversion of received light to electrical signals.

The medium propagation modeling portions of IMPERSonator in principle require in-situ profiles at the system wavelength (532-nm in the case of LS4096) of ambient light, the absorption coefficient, and the differential scattering cross section. The target scattering modeling requires digital target images for target shape and for wetted reflectivity measurements.

In practice, measurements were made at the feasibility demonstration test site of ambient light at the surface and of profiles of the absorption coefficient and small-angle forward scattering. These measurements were made continuously during the execution of the feasibility demonstration. The differential scattering cross section was modeled from the measured absorption and small-angle forward scattering profiles by assuming a standard "Maalox" scattering for the medium.

With these profiles, typical attenuation lengths during the feasibility demonstration were around 1.5 meters. Since the field of view of LS4096 is 70 degrees (centered on nadir) and the operating height was generally four to five meters, the ranges to the targets during the feasibility demonstration were generally between four and six meters (roughly 2.5 to 4 attenuation lengths).

Figure 22 shows a comparison between two actual LS4096 target images (first column) and images simulated by IMPERSonator (for the experimental operating conditions under which the actual images were taken) for the LS4096 (second column) and images simulated for a simple passive camera (third column). Notice the flattened appearance of the simulated targets. The simulated images for the passive camera were obtained using ambient light for illumination, and so represent the performance of a simple camera at its best (nighttime operation would require artificial illumination, backscatter from which typically grossly limits the maximum useful range of a simple camera).

FIGURE 20. LLS IMAGE OF 60-MM MORTAR SHELL

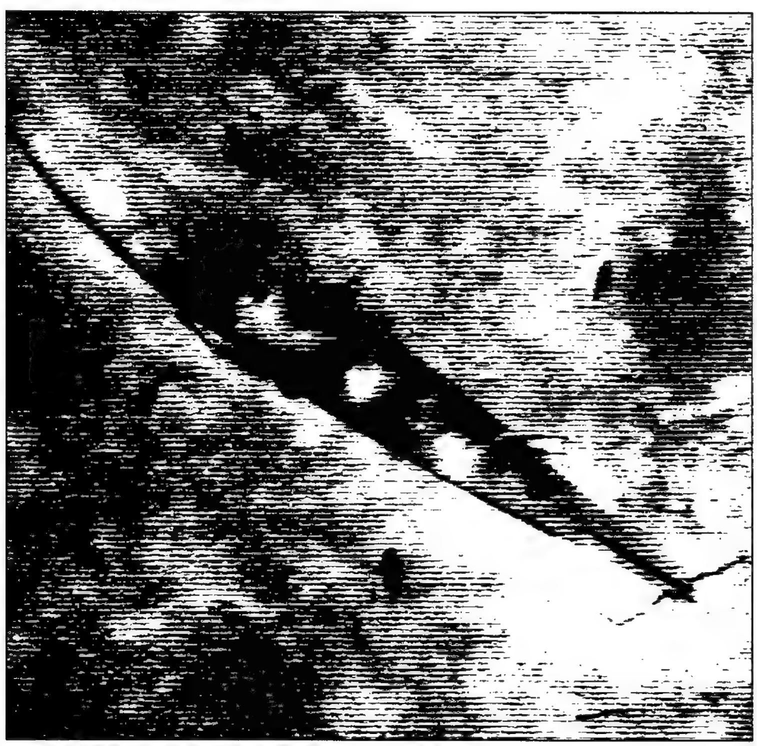

FIGURE 21. LLS IMAGE OF 2000-LB (908 KG) BOMB

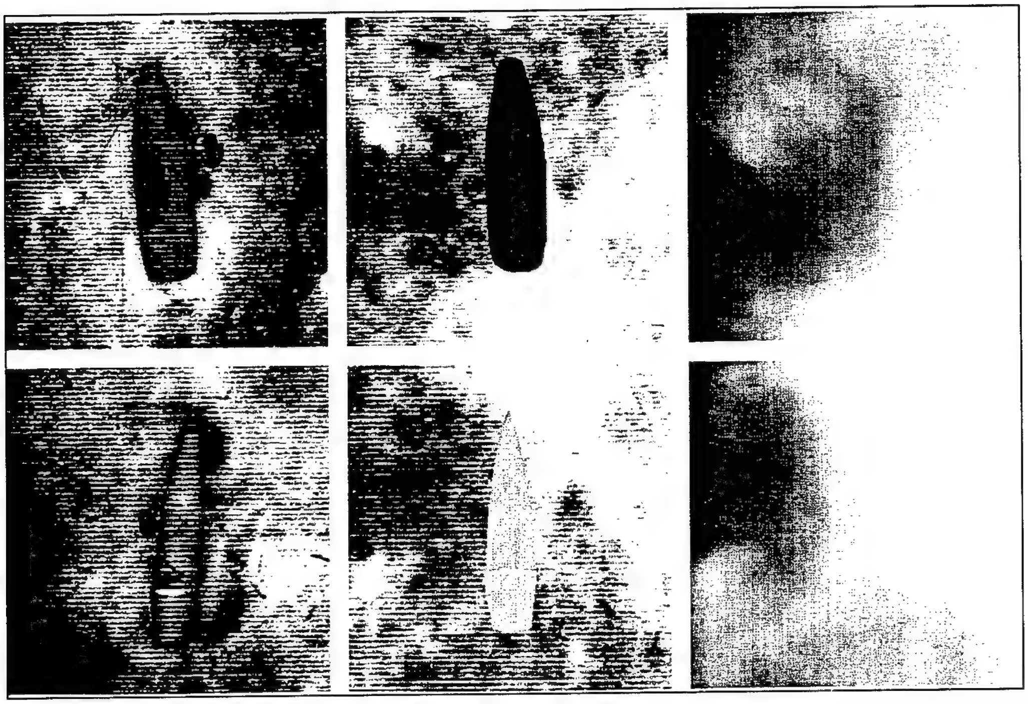

FIGURE 22. LLS (FIRST COLUMN) AND SIMULATED IMAGES (SECOND AND THIRD COLUMN)

ST. ANDREWS BAY FEASIBILITY DEMONSTRATION CONCLUSIONS

The MUDSS acoustic, magnetic and EOID sensors operated together in the MUDSS configuration as required and demonstrated successful acoustic imaging, magnetic localization and moment classification and EOID imaging of a set of UXO targets of varying size from small mortar shells to 1000-lb (454 kg) bombs (See Figure 23). Tests were limited to proud targets. Phase I results also demonstrated the towing capabilities and requirements of the multi-sensor package of all three sensor types together, acoustic, magnetic and electro-optic. Primary accomplishments of the Phase I MUDSS test were:

- The tests proved the MUDSS configuration and target detection were feasible.
- The MUDSS sensors could provide accurate target position results at acceptable range when operated from stable tow vehicles. MUDSS feasibility demonstration tow vehicles operated within the envelope of +/- 1 degree of roll, pitch, and yaw in the benign St. Andrews Bay environment.
- The tests showed that CSS performance models SWAT for acoustic and IMPERSonator for EOID accurately predicted performance. This was important in designing the upgraded acoustic and EOID sensors that were developed for the MUDSS technology demonstration system.

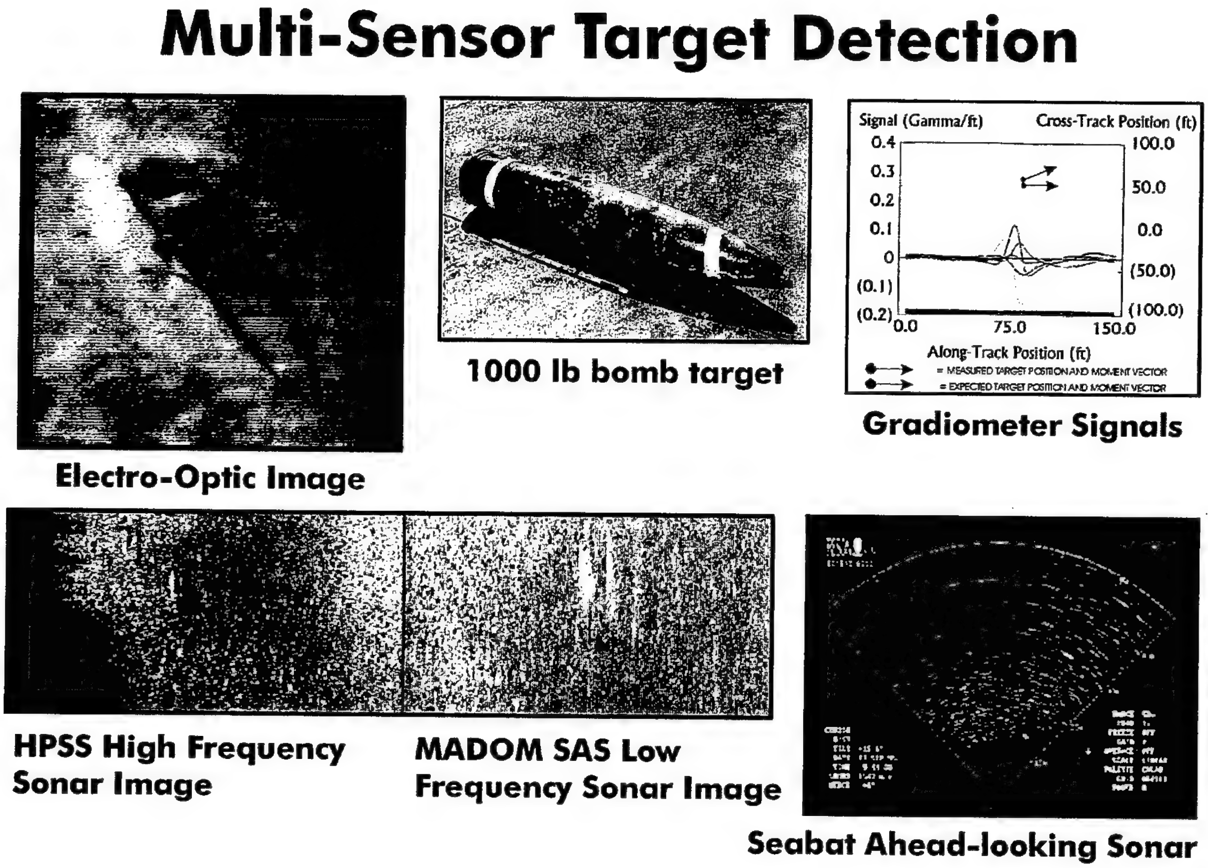

FIGURE 23. MUDSS MULTI-SENSOR TARGET DETECTION

PHASE I: 1996 HALIFAX TRACE EXPLOSIVE DETECTION FEASIBILITY DEMONSTRATION

The goal of the MUDSS project is to address the underwater cleanup problem of UXO by demonstrating the technologies necessary for shallow, underwater surveys. The MUDSS survey concept includes application of a trace explosive detection technique developed by JPL as a method for confirming the identity of buried UW UXO.

Demonstration of chemical detection of UXO was tested in Halifax Harbor, Canada in 1996 as part of the MUDSS Phase I Feasibility Demonstration. This test determined the effectiveness of the Reversal Electron Attachment Detector (READ) for detecting trace explosives in soil samples collected from a known UXO site.

UXO SITE IN HALIFAX HARBOR, CANADA

The site chosen for trace explosive detection was offshore of Rent Point in Halifax Harbor, Canada because of the large amounts of UXO known to be in this area. During the Second World War, Halifax, Nova Scotia was a nexus for convoys destined for Europe. When the war ended, ships returning from Europe unloaded live ordnance of every type at Halifax, filling the relatively small munitions bunker there. A minor fire in 1945 caused detonation of the entire complex and for ten days explosions scattered large quantities of UXO around and into the harbor. Subsequently, a modest cleanup was pursued on land, but no effort was made to clean up the sea floor of Halifax Harbor or Bedford Basin. The nearby shoreline was restricted to military personnel and the underwater UXO in the area were left undisturbed. Hence, all of the ordnance at Halifax could be expected to be live rounds with few if any inert rounds. Since the UXO had lain undisturbed for over 50 years, Halifax Harbor was an ideal location for testing of trace explosives detection.

Through discussions with Canadian Armed Forces personnel, possible sites where dive teams could sample UXO were identified. The nearest site was off Rent Point in the Bedford Basin, adjacent to the ammunition bunker used by the Canadian Armed Forces (See Figure 24). This was chosen as the site from which collections would be made.

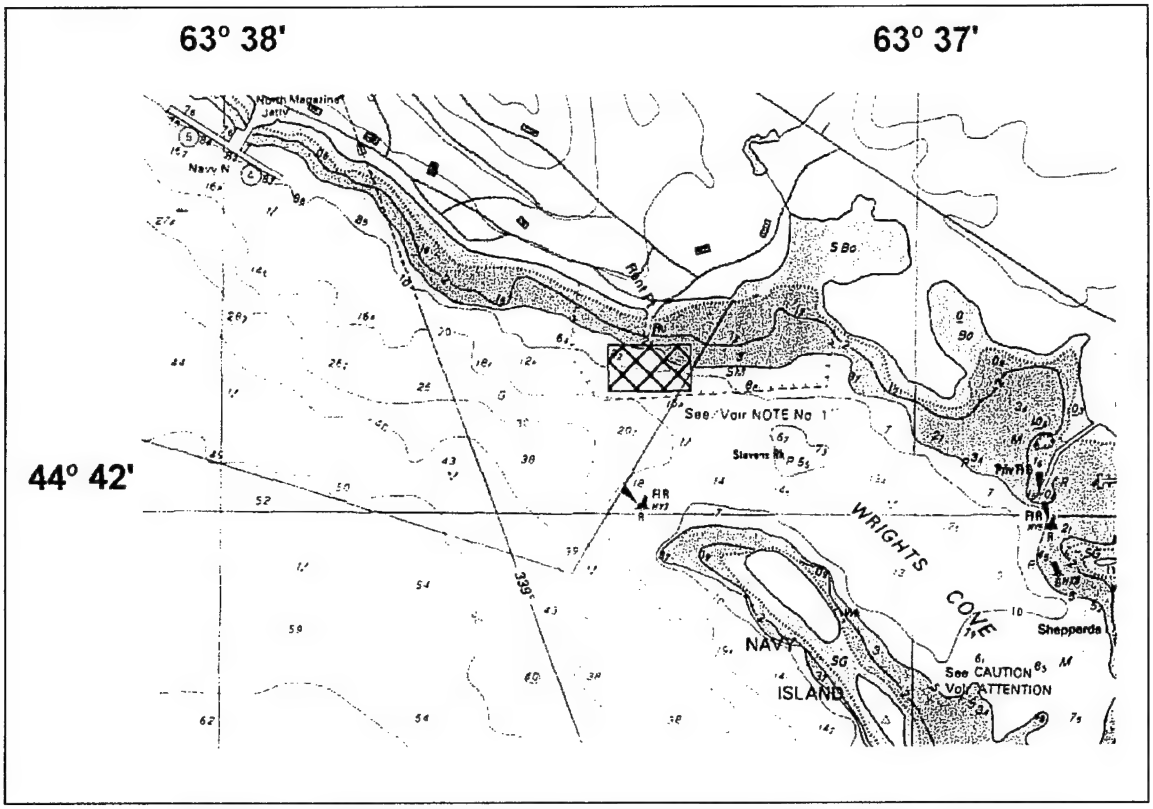

FIGURE 24. NAVIGATION CHART SHOWING RENT POINT TEST AREA

SEDIMENT SAMPLING AROUND UNEXPLODED ORDNANCE (UXO)

The services of the Harbor Inspection Dive Team of the Canadian Armed Forces Reserves were kindly offered to collect the sediment near UXO. First, the dive team surveyed a portion of the seabed, locating, marking, and videotaping target UXO. Second, the dive team returned to shore and the videotape was reviewed to identify which UXO should be sampled. Intact and damaged UXO targets are shown in Figures 25 and 26. Third, the dive team returned to the agreed upon UXO and obtained sediment samples from an area around the UXO that was no closer than six inches and no further than twelve inches. The collection was also videotaped. One sample was taken from each of the four cardinal points around the UXO, for a total of four samples for each UXO. The aggregate amount of sediment collected was approximately 25 ml of a sediment water mixture for each target. Fourth, the samples were returned to the surface and labeled.

Samples obtained the first day remained at ambient temperature for no longer than six hours before being placed in a commercial freezer after the day's collection was complete. The holding times of nitroaromatic and nitramine explosives in water and soil have been extensively studied. Studies show that the holding time for trace explosives can be up to 90 days provided the samples are stored in salinized containers and frozen immediately after collection.

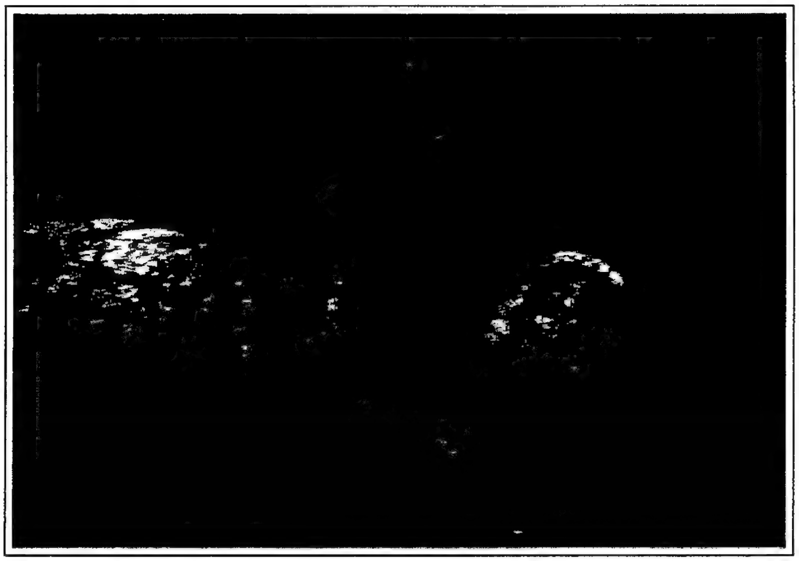

FIGURE 25. TWO 5-IN (12.7 CM) SHELLS, BROKEN OPEN

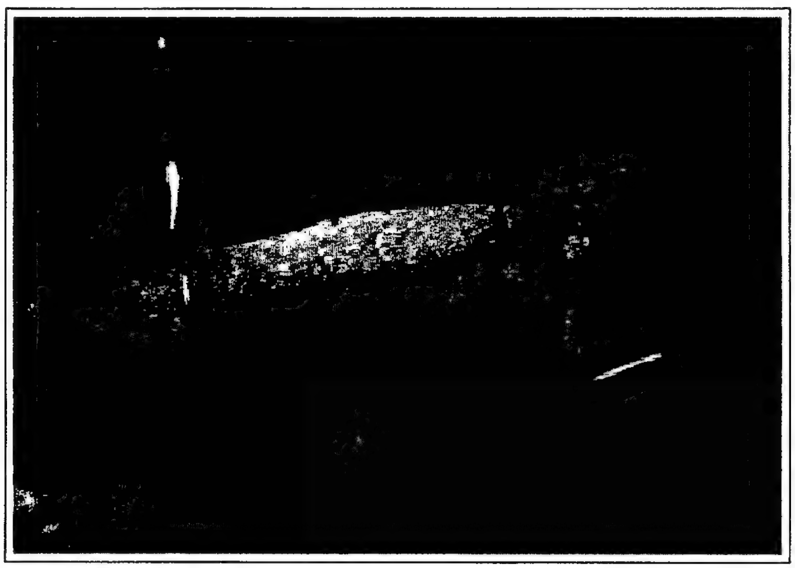

FIGURE 26. FIVE-INCH ARTILLARY SHELL, INTACT

During the second day of sampling, the dive teams were sufficiently experienced to obviate the necessity of returning to the dock for review of the videotape before sampling. Videotaping of each of the targets on the second day was performed before and during sample collection.

As was experienced during the first day of sampling, the amount of silt displaced into the water during sediment collection made it impossible to ascertain where the samples were taken

on each target. The Dive team confirmed only that the samples were obtained from the four cardinal directions. Sample collection was identical in all other aspects to the first day of sampling.

Before shipping it was verified that all samples were frozen. The bottles were placed in large boxes and packing foam injected to completely protect and insulate the samples. Samples were shipped as checked baggage on a commercial airliner and they remained frozen during the entire trip back to JPL, where they were immediately placed in a commercial freezer.

EXPLOSIVES DETECTION

The samples were brought back to the laboratory at JPL and processed as follows:

1. Any explosive material traces were extracted using solid-phase microextraction (SPME).
2. The extracted species were detected using the Reversal Electron Attachment Detector (READ) technique.
3. For verification in some cases, the extracted species were also detected using a commercial gas-chromatography/mass spectrometer (GCMS).

Given the types of explosive fillers used in artillery shells during World War II it was determined that the sediment samples should be examined for TNT and RDX. Since dinitrotoluene (DNT) isomers constitute the major trace chemical in TNT manufacture, the sediment was examined for this as well.

Sample Preparation: SPME Extraction

The extraction procedure was started by removing the four samples, corresponding to a particular UXO target from the freezer and allowing them to thaw. In instances where there was less than 100 grams of sediment in each of the four samples, they were aggregated into two separate samples into two salinized glass beakers for that UXO target.

100 ml of methanol or acetonitrile was added to each of the samples and the slurry placed in a sonic bath for a period of at least one hour. Samples were sonicated by the direct method in which the sample beakers were place in a larger perforated metal basket that was suspended inside the sonic bath. Soil motion was visible during the whole sonication period. At the end of sonication, the soil and liquid layers were allowed to separate, and the liquid layer was pipetted off into a separate clean, salinized glass beaker. These glass beakers containing the pipetted water/solvent mixture were then desiccated to dryness inside a vacuum bell jar connected to a dry-ice cooled cold trap. After desiccation was complete, 250 ml of water was added to each sample and sonicated for an additional hour. After sonication, the aqueous solutions were suitable for extraction using a Supelco brand Solid Phase Microextraction (SPME) poly (dimethylsiloxane) divinylbenzene fiber.

Samples were prepared, extracted and analyzed within three hours of being first removed and thawed from the freezer. Aqueous redilutions were not allowed to remain at room temperature for longer than one hour, minimizing losses from photodegradation of any explosive traces in the samples. Typically, with aqueous solutions bearing parts-per-billion TNT concentrations, five or six extractions could be performed before depletion of the samples was detected.

The addition of salt, or adjustment of the solution's pH can increase the ionic strength of the solution thereby reducing the solubility of some analytes. For the MUDSS study, no increase in extraction efficiency was found when salt was added; seawater and distilled water yielded the same efficiencies. It was decided to adjust to pH 8 the solution from which extractions were made.

Since ample agitation enhances extraction and hence reduces extraction time, a bubble aeration scheme was used to agitate the sample during extraction. This technique minimized possible losses through adsorption of trace explosives to stir bars. A 10-ml pipette tube was salinized, cleaned with methanol, and connected to a source of N_2 (99.99% pure). With the bottom 2-3 mm of the tip of the pipette inside a solution, the gas feed was adjusted so that a gentle bubbling of the liquid was achieved. To minimize cross contamination between extractions, the pipette was discarded and replaced with a freshly salinized one, or cleaned thoroughly with methanol when samples were changed. Equilibrium times for the adsorption of possible explosives derived from the original Halifax samples into the SPME fiber were found to be approximately five minutes; to ensure consistent results all extractions were performed for fifteen minutes. Since even small amounts of water were found to be detrimental to the cathode of the READ electron gun, after extraction the SPME fiber was dried in a vacuum desiccator for at least fifteen minutes before injection of the fiber into the desorption oven. The extraction method is illustrated in Figure 27.

Reversal Electron Attachment Detector (READ) and Explosives Detection

The READ system uses the fact that explosives molecules have an extremely large cross section for attaching zero-energy electrons. This cross section varies as $1/v_e$ where v_e is electron velocity. Hence, the attachment rate (or ionization efficiency) is favored for slow electrons. The READ system provides a large density of electrons with zero and near zero velocities by stopping and reversing, using a shaped electrostatic mirror, the current from an electron gun column. The analyte is introduced to this stopping region, and upon attachment each explosives type forms a characteristic negative-ion fragmentation pattern. Using a quadrupole mass spectrometer, the READ monitors one or more fragment peaks to detect the species, and with calibration, to provide concentration levels. See Figure 28.

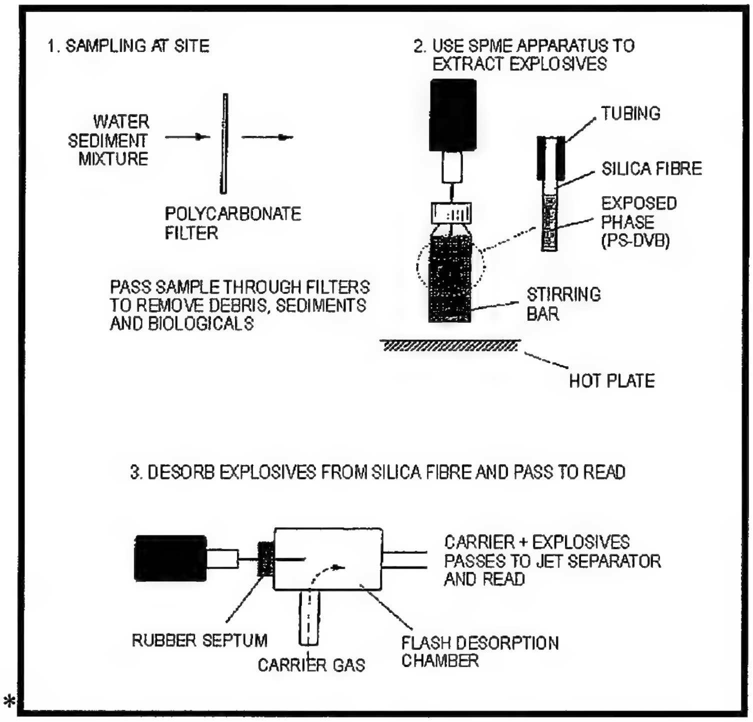

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FIGURE 27. EXPLOSIVE EXTRACTION METHOD

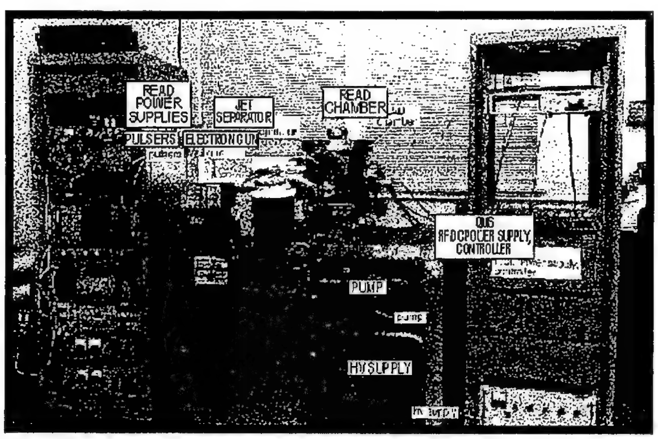

FIGURE 28. REVERSAL ELECTRON ATTACHMENT DETECTIOR

Thermal desorption of any explosives from the SPME fiber must be performed at a high temperature, suggested by Supelco, Inc. to be slightly above the boiling point of the analyte. At this temperature the desorption process takes from one to two minutes. During the one to two minutes the explosives were desorbing from the fiber, the quadrupole mass spectrometer could be tuned to various mass peaks. Mass locations and assignments for TNT are listed in Table 2.

TABLE 2. MASS NUMBERS AND IDENTIFICATIONS OF FEATURES IN THE ZERO ENERGY ATTACHMENT SPECTRUM OF TNT

Mass	Identification
46	NO_2^-
77	$(TNT\text{-}NO_3\text{-}NO_2\text{-}CNO)^-$
105	$(TNT\text{-}2NO_2\text{-}NO)^-$
109	$(TNT\text{-}NO_2\text{-}CNO\text{-}NO)^- OH(NO_2)_2^-$
120	$(TNT\text{-}2NO\text{-}HNO_2)^-$
137	$(TNT\text{-}3NO)^-$
139	?
151	$(TNT\text{-}NO_2\text{-}NO)^-$
167	$(TNT\text{-}2NO)^-$
181	$(TNT\text{-}NO_2)^-$
197	$(TNT\text{-}NO)^-$
210	$(TNT\text{-}OH)^-$
227	$(TNT)^-$

If ions with a mass-to-charge ratio (m/e)=227 and 197 were detected it would indicate that TNT was present in the SPME extraction. If these ions were absent but ions with m/e = 182, 167 and 151 were detected, an isomer of DNT was present in the SPME extraction. The SPME results for the sediments collected near Halifax UXO are summarized in Table 3.

TABLE 3. SPME/READ EXPLOSIVES TEST ON SAMPLES COLLECTED AT HALIFAX, NOVA SCOTIA, CANADA

Target No.	Target Type	Samples	Results
1	5" Shell Poor Condition Broken Open	A, B, C, D	No explosives detected
2	5" Shell Very Poor Condition Broken Open	E, F, G, H	No explosives detected
3	5" Shell Good Condition Intact	L, I	No explosives detected (confirmed by GC/MS)
		W, X	TNT Detected at low ppb concentrations
4	9 Shell Semi-Buried Appeared Intact	K, L	TNT Detected at high pptr concentrations
		M, N	No explosives detected
5	Two 5" Shells Very Poor Condition Broken Open	O, P, Q, R	No explosives detected (confirmed by GC/MS)
6	5" Shell Semi-Buried Intact	T	DNT detected at low ppb concentration (confirmed by GC/MS)
		S, U, V	No explosives detected (confirmed by GC/MS)
7	Background Sediment Sample	17, 20	No Explosives Detected (confirmed by GC/MS)
8-12	Samples degraded — not used		

Verification with the GC/MS

As an independent test of the READ analysis, the solvent extracted material from three different sediment samples were split and analyzed by GC/MS for the presence of trace TNT or DNT. The samples were chosen before any READ testing was performed, on the basis of their color. Typically, the solvent extractions had varying hues of yellow and the samples chosen for GC/MS analysis were almost colorless or a strong yellow. The methanol/water mixture was extracted using 25 ml of methylene chloride, pipetted, dried over sodium sulfate and then evaporated to 1.5 ml under a stream of dry nitrogen. An injection of a 4-:l sample into a Finnigan Incos XL model GC/MS was used for analysis. The colorless samples were evaporated to dryness and then rediluted in a smaller amount of methylene chloride for analysis. This was done to lower the detection limit since the samples were not as dark yellow in color. In evaporating the samples, some of the early eluting peaks in the GCMS analysis were unavoidably lost due to their higher volatility. The compounds identified in the GC/MS for Target 6 [five-inch shell (12.7 cm), semi-buried, intact] are summarized in Table 4. The sediment sample from Target 5 [two 5-in (12.7 cm) shells, not intact] yielded no detectable DNT or TNT at the 200-ng detection limit.

TABLE 4. SUMMARY OF SOME OF THE COMPUNDS IDENTIFIED IN GC/MS ANALYSIS OF SEDIMENTS NEAR TARGET 6

Compound ID	Scan Number	Yield
trimethylhexene isomers	388-426	490 :g
3-ethyl-1-octene	537	390 :g
tetramethylpentane	597	25 :g
DNT	928	1.1 :g
TNT	1022	not detected(< 200 ng)
tetradecanoic acid	1033	18 :g
hexadecanoic acid	1067	31 :g
benzopyranone compounds	1105	250 :g
fluoranthene	1194	5 :g
pyrene	1219	12 :g

HALIFAX FEASIBILITY DEMONSTRATION CONCLUSIONS

A solid phase microextraction (SPME) method was successfully developed and optimized at JPL for extracting trace explosives from seawater. This technique was interfaced to the READ explosives-detection system, and standard tests were conducted to determine sensitivities to TNT as a function of analyte concentrations. Ultimate detection sensitivities of 10 pptr were observed for TNT in water.

A detailed study of sediments present near live underwater ordnance was made at Halifax Harbor, Canada, the site of a massive explosion in 1945 in which live, unexploded, World War II ordnance was scattered into the harbor. With the aid of divers from the Canadian Armed Forces, sediment samples near twelve targets were collected and analyzed at the four cardinal points around each target. Analysis showed that sediment collected near rounds that appeared (from visible inspection) to be broken open showed no evidence of TNT at the 10-pptr level. Samples near targets that appeared intact showed trace explosives chemicals up to the parts-per-billion in concentration. For the intact rounds, positive results were found at only two of the four cardinal points, indicating directionality to the source. One may conclude from this that, in the fifty years since the Halifax explosion, broken munitions have had their contents dissolved, reacted, biodegraded or perhaps even photodegraded. On the other hand, intact munitions appear to be releasing their contents as a slow leak, very likely through pinholes in the eroded casing, or through the screw threads linking the fuse assembly to the main charge. Presumably, the signal strength is stronger near the point of emission; hence the directionality within the sediment samples.

PHASE II: 1998 MUDSS TECHNOLOGY DEMONSTRATION CHOCTAWHATCHEE BAY TESTS

A MUDSS technology demonstration (TD) was conducted in November 1998 at Choctawhatchee Bay (CB), Eglin AFB, FL to demonstrate MUDSS UXO survey capability at a real-world underwater UXO site and specifically to determine the location of residual WWII practice bombs. A map of the site area is shown in Figure 29. Preliminary evaluation of archival data on the CB site indicated that the test area included an undetermined number of 250-lb (113 kg) and 500-lb (227 kg) aerial-dropped practice bombs located in 15-30 ft (4.6-9.1 m) water depths in sandy and muddy bottom regions. A key TD objective was to demonstrate the value of the flexible, multi-sensor MUDSS in coping with real-world UXO survey problems such as difficult operational environments, buried UXO and UW clutter/debris.

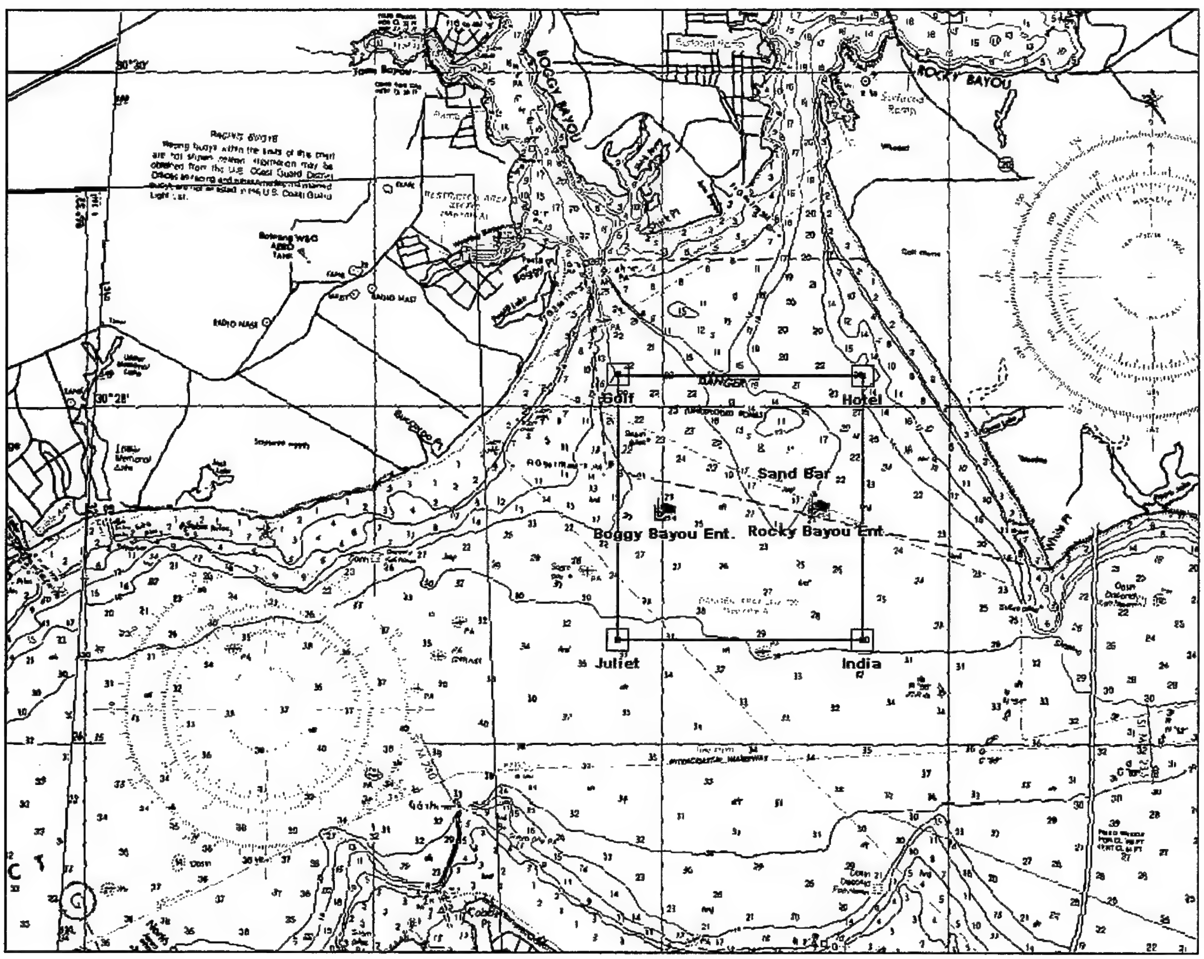

FIGURE 29. CHOCTAWHATCHEE BAY TEST SITE

MUDSS TECHNOLOGY DEMONSTRATION SYSTEM CONFIGURATION

MUDSS TD System is configured as shown in Figure 30 and includes upgrades from the MUDSS FD System in the areas of sensors, towed vehicle system, data collection and processing electronics, and display electronics. MUDSS TD system upgrades were designed to provide maximum sensor detection and identification capability, electronics to provide real-time sensor UXO detection and imaging capability, GPS equipment to provide real-time target mapping and display electronics to provide real-time mapping.

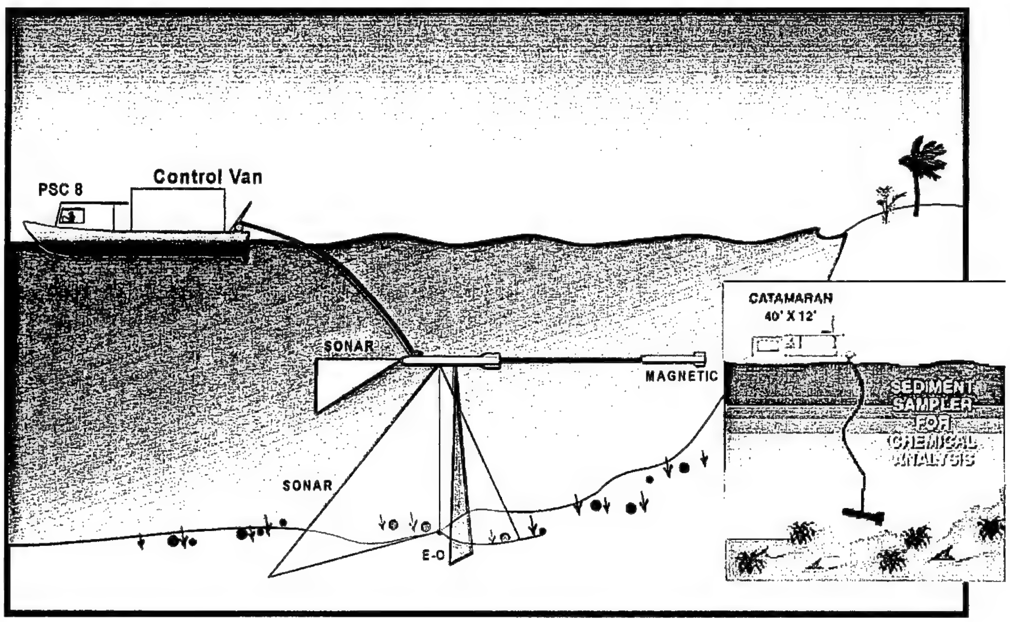

FIGURE 30. THE MUDSS TD SYSTEM CONCEPT

Major differences from the 1995 MUDSS Feasibility Demonstration System include:

- A new dual sided, dual frequency SAS sensor.
- An upgraded, compact [21-in (53 cm) dia, 36-ft (10.6 m) long] EOID sensor compatible with MUDSS lead tow body.
- A new two-body MUDSS tow system with an active-wing lead tow body for improved control of tow depth and tow body stability.
- Addition of computers in the tow body for real-time sensor data processing during survey.
- Addition of a DGPS system to provide real-time global positions of MUDSS detected targets.
- Addition of sonar displays for the SAS sonar for survey operators.
- Addition of Melian survey software for organizing and conducting the survey
- Addition of displays for sensor control and display of real-time sensor and survey data.

MUDDS TD SENSORS

The MUDSS TD five-sensor suite (Figure 30) includes three sonars, a magnetic field gradiometer, and an electro-optic sensor. The prime MUDSS detection and identification sensors were developed by the Navy (ONR) for detection of underwater mine-like targets. The sixth sensor, a developmental sensor for detecting trace chemical explosives, was developed by JPL for NASA.

Acoustic Sensors – HF/LF SAS; SeaBat

The MUDSS TD included a double sided, dual frequency HF/ LF SAS. The HF 180-kHz SAS provides high resolution (2.5-cm x 2.5-cm) images of proud bottom targets; the LF 20-kHz SAS provides high resolution (7.5-cm x 7.5-cm) images of proud and shallow buried targets. The resolution figures apply when the sensors are towed at eight knots. For the HF SAS, targets are identifiable as bright images with a characteristic shadow, providing additional shape information. For the LF SAS, the target has only a bright image with no shadow. The HF/LF SAS sonar shown in Figure 31 is described in Appendix A.

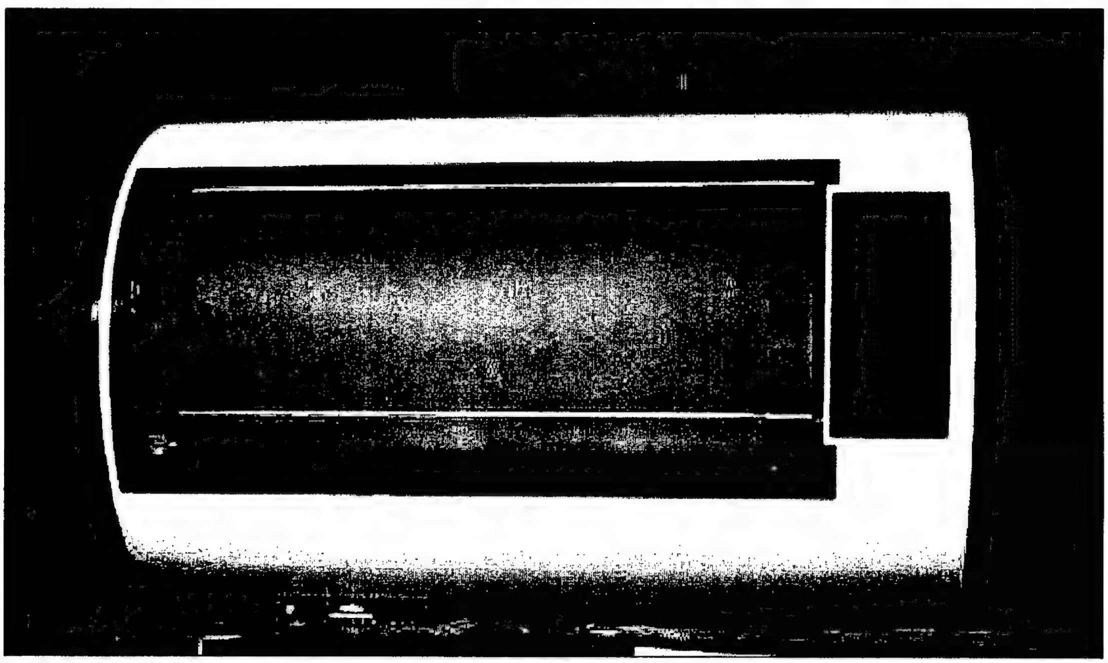

FIGURE 31. MUDSS TD HF/LF SAS SONAR

The SeaBat sonar (Fig, 32) provides a forward look capability for target detection, reacquisition, and/or obstacle avoidance. SeaBat targets are depicted as a bright spot in the sonar image. The SeaBat is also described in Appendix A.

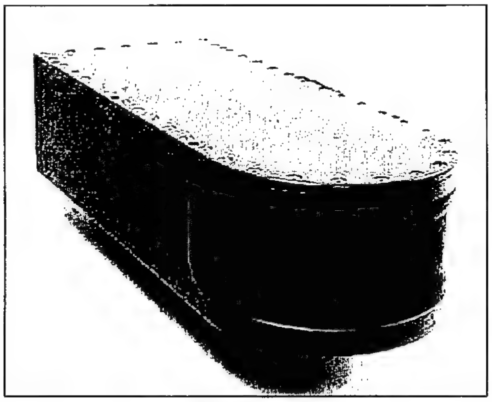

FIGURE 32. MUDSS TD SEABAT SONAR

Magnetic Sensor – SGMS

A cryogenically cooled, superconducting magnetic field gradiometer (Figure 33) also provides MUDSS with a proud and buried target capability. The MUDSS TD magnetic sensor senses five independent target magnetic gradients that are processed to calculate the target position and magnetic moment vector. The target magnetic moment, a function of the ferrous mass, provides target classification information that is a valuable complement to the shape information provided by the acoustic sensors. Gradiometer sensitivity of three pTesla/meter is achieved in MUDSS towed operation. Details of the SGMS sensor are provided in Appendix C.

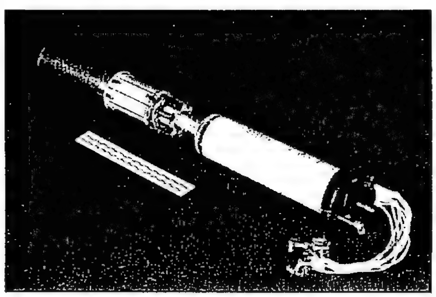

FIGURE 33. MUDSS TD MAGNETIC FIELD GRADIOMETER

EOID Sensor

The Raytheon-developed laser line-scan electro-optic sensor (Figure 34) provides visible images of targets (with 6-mm resolution) at attenuation lengths three to five times greater than the human eye alone. On a close-range pass (approximately 5 m), the electro-optic sensor provides high-quality target identification imaging. Details of the LLS are provided in Appendix B.

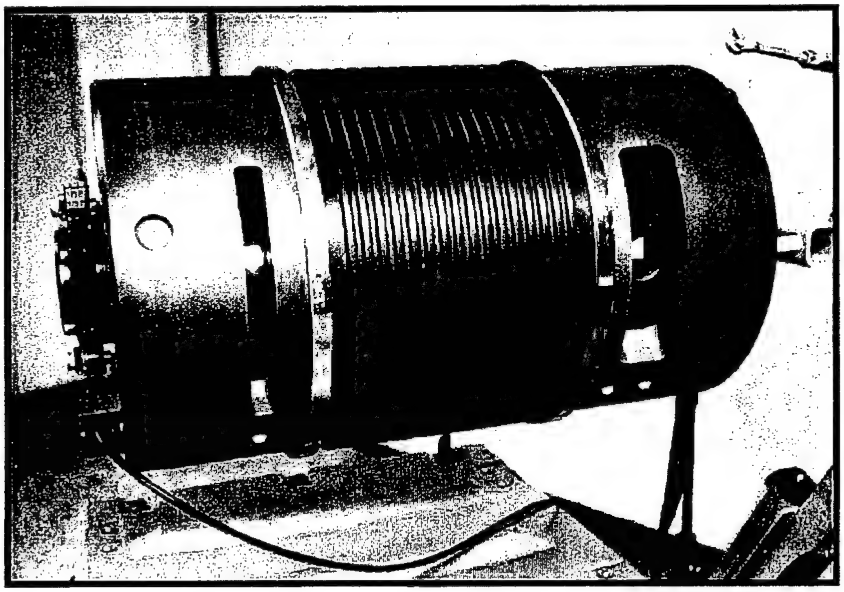

FIGURE 34 MUDSS TD LASER LINE SCAN ELECTRO-OPTIC SENSOR

Trace Chemical Sensor

A sixth sensor for detecting trace chemical explosives is also a part of the MUDSS system. In the MUDSS technology demonstration sediment samples are taken at selected bottom sites and sent to JPL for laboratory analysis. Details of the JPL sampling technique have been described in a previous section.

MUDSS TD TOWED SYSTEM

MUDSS TD towed system includes two towed bodies. The first body is an active tow body designed to permit selection of tow depth and highly stable tow operation for the enclosed SAS and LLS sensors. The second body is a neutrally buoyant passive towed body housing the magnetic sensor. The second vehicle operates from a pigtail cable 75 ft (23 m) behind the first vehicle. Figure 35 shows major MUDSS subsystems housed in the towed bodies.

Active Tow Body System

The primary purpose of the active tow body is to provide stable deployment of the MUDSS sensors, and house equipment for processing of SAS images and magnetic target localization and supporting the magnetic sensor. The tow body contains:

- Multiplexer (MUX) for conversion of control and status data to/from a single data stream for transmission to the surface to and from multiple data streams for the tow body components
- Active wing for altitude control of leading tow body, and for low data rate transfer through the tow cable to the control van on the tow platform

- Active tail for altitude control of leading tow body
- SeaBat sonar for obstacle avoidance and EOID target reacquisition
- SAS for side scan sonar imaging
- Motion measurement package for tow body altitude and water sound velocity measurements for the SAS image processing
- EOID laser line scanner for target reacquisition imaging and identification
- A 10 billion floating point operations per minute embedded real-time processing system (GEM) computer for processing raw SAS ping data into side scan sonar images, running target recognition analysis on the sonar images, magnetic target localization from raw gradiometer data, and high data rate transfer up the fiber optic line in the tow cable to the control van on the tow platform
- Helium pump for venting excess helium gas from the SGMS in the trailing tow body

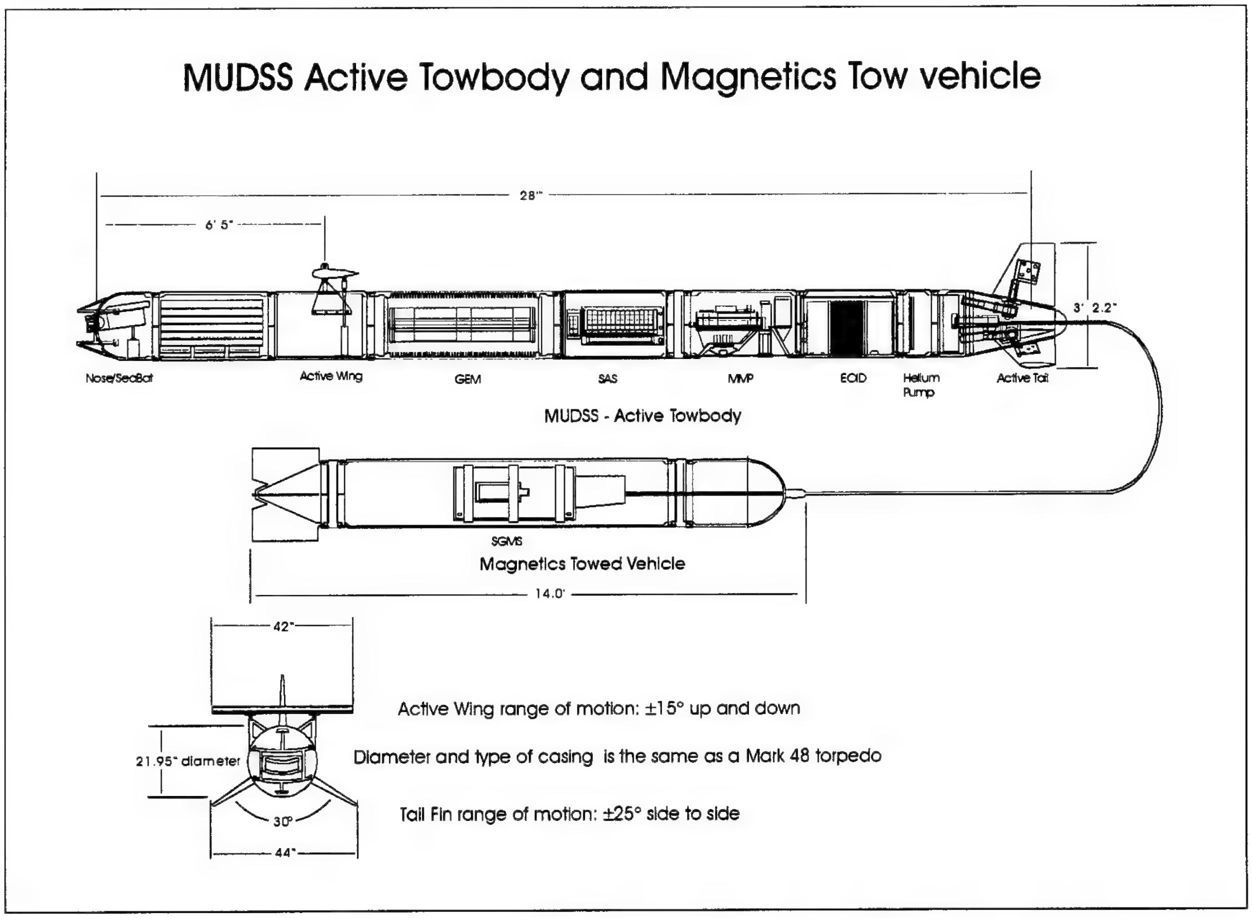

FIGURE 35 MUDSS TD ACTIVE TOW BODY AND TOW VEHICLE

Magnetic Tow Vehicle System

The primary purpose of the magnetic tow vehicle is the deployment of the MUDSS magnetic sensor, the SGMS, separate from the other sensors and electronic noise sources in the leading, active tow body. The magnetic tow vehicle only contains the SGMS sensor in its liquid helium-cooled containment vessel and the data link for pre-processing and transmission of sensor data. The passive tow vehicle is connected to the active tow body by a cable through which the SGMS data link transmits data and the SGMS vents excess helium gas.

MUDSS TD TOW PLATFORM SYSTEM

The primary purpose of the tow platform is to provide for the towed deployment of the sensors, MUDSS operation power and facilities for control, display and recording required during MUDSS TD operation. The tow platform system includes:

- The tow platform itself, *PSC 8*
- Winch and cable for towing--the cable also has fiber optic and copper wires embedded in it for high and low data rate transmission to and from the tow body
- The MilVan control center located on the deck of the tow platform
- The cabin of *PSC 8*, where MUDSS analysis and data display computers are located

The control van on the deck of the towing platform operates as a control center for the MUDSS sensors and tow body. Selected search planning and data visualization are performed in the control van as well. The control van contains:

- Low data rate multiplexer (MUX) for conversion of data to and from a single stream, for transmission through the cable to the active tow body to and from multiple data streams, for electronics shack computers
- Active tow body wing and tail control
- SGMS control
- SeaBat display (a second display is provided for the *PSC 8* boat pilot as well)
- A custom multiple touch-screen display computer, the Eliot sensor display; includes two screens for SAS display (one of these also serves as EOID display when that sensor is operating), and another screen for sensor control
- Tow body control laptop computer
- The visualization Silicon Graphics Incorporated (SGI) computer

The cabin space area contains processing, playback and analysis computers for the MUDSS TD, including:

- A SUN Sparc Station for running Melian, the search track planning and plotting software, modified version supported by JPL
- Control, output and display for the GPS

Melian is a search planning and survey software package offered by Daniel H. Wagner Associates, Inc., which was used in conjunction with MUDDS (Melian II,1998, is described at http://frontpage.wagner.inter.net/Melian Pages/ MELIANdetail.html) The MUDSS system uses a version of Melian modified by JPL for the MUDSS system. The GEM computer sends data up to the Eliot display computers and then time, location, and target information is passed on directly to the Melian database. Details of the MUDSS TD planning, operation, processing and display system are provided in Appendix D.

For the MUDSS system, Melian is accessed via a JPL program, VISSYS, resident on the SGI computer, which is networked to the SUN Sparc Station on which Melian is running. VISSYS accesses the Melian database, displays navigational charts and marks contact locations on the charts displayed on the SGI computer. Melian will sort the SAS and SGMS contacts that have the same location (and so are the most likely UXO targets) and will produce a list of latitude and longitude locations for them. Very large SGMS contacts that were not detected by the SAS would also be considered potential buried UXO targets. These locations were passed on to divers gathering sediment samples for chemical detection at JPL.

Additional details of control, display and processing subsystem are presented in Appendix D.

MUDSS TD COVERAGE PATTERN

MUDSS operates in a target search mode followed by a reacquisition and target identification mode. In the search mode MUDSS HF/LF SAS and magnetic sensors are the primary detection and localization sensors and the towed vehicles are operated near the bottom [~ 10 ft (3 m) above bottom] due to poor acoustic and optic environment. The SAS sensor search range is 40 m at eight knots. The SAS search width is 80 m with a holiday ten meters wide directly below the towed vehicle. The magnetic sensor detection/localization range is target magnetic size dependent. For a 500-lb (227 kg) bomb the range is 20-25 m. The magnetic sensor search width is approximately 40 m for a vehicle towed ten feet (three meters) above the sea bottom. There are no holidays in the magnetic sensor search path. During the CB survey MUDSS executes parallel track paths separated by 27 meters (92 tracks across 1.4 nautical miles for survey area). This provides approximately 50% overlap on adjacent magnetic search tracks and multiple SAS coverage such that the holidays are covered by adjacent search tracks.

MUDSS uses the EOID sensor for target identification when targets are proud and water visibility permits. The LLS sensor has a +/- 70° field of view below vertical on either side of the tow body and when the tow vehicle is operated ten feet above the sea bottom, the LLS sensor has a search width with good imaging of 14-16 ft (4.3-4.9 m). The narrow EOID imaging width reaffirms the need for the SeaBat sonar for successfully reacquiring the target and permitting tow craft steering adjustments to position the tow vehicle within imaging range of the EOID sensor

TD TEST DESIGN GOALS

MUDSS Tech Demo included several goals directed at mapping the UXO at the Choctawhatchee Bay site. These included:

- Conduct environmental measurements at the Choctawhatchee Bay site of the sound velocity, optical attenuation and scattering in the search area to predict MUDSS sensor performance and adjust MUDSS search tactics to maximum UXO mapping performance.
- Conduct MUDSS mapping tests against a set of UXO test targets to validate MUDSS operation and mapping performance in the Choctawhatchee Bay environment.
- Plan and execute a UXO search and map the UXO in the two square nautical miles Choctawhatchee Bay search area.
- Verify identification of detected UXO targets by EOID UXO image validation whenever possible, and by Navy diver reacquisition/inspection and trace explosive sampling where necessary.

MUDSS TECH DEMO EXECUTION AND DATA ANALYSIS

The MUDSS survey plan included activities to measure and characterize the CB site environmental parameters, to measure MUDSS performance against a set of test targets and to conduct a comprehensive UXO survey of the test area. The survey included a search phase to locate potential UXO targets using the MUDSS acoustic and magnetic sensors, and a confirmation phase where potential targets were verified using MUDSS EOID sensor for proud, visible targets. Divers were to be used to investigate and verify detected targets that were buried and not visible.

Environmental data measurements were scheduled daily at several sites in the test area (see Figure 36). Measurements of sound velocity profile (SVP) and light attenuation and absorption characteristics were made to ascertain the site acoustic reflection conditions and water clarity. Site environment conditions were used to determine and set the sensor tow depth for optimum MUDSS survey performance. Figure 36 also identifies the location of a set of test targets used to measure MUDSS performance against known targets. Test targets included: a group of two 60-mm mortar shells, a 500-lb (227 kg) bomb, a 1000-lb (454 kg) bomb, a 155-mm howitzer shell, and an Aluminum (AL) panel. Target tests were designed to confirm MUDSS acoustic and magnetic sensor detection/localization performance, MUDSS processing algorithm performance, and MUDSS reacquisition tactics and EOID target verification performance against a known set of targets.

The MUDSS plan was to conduct the UXO survey by performing a set of parallel search tracks (see Figure 36) using the HF/LF SAS sensor and magnetic gradiometer array sensor to detect and locate the position of potential UXO targets, tagging the potential UXO target locations with GPS coordinates. Acoustic identification of UXO targets was determined by operator inspection of the acoustic images on the real-time MUDSS acoustic display.

Potential UXO targets would be independently detected and localized from the magnetic data using processing algorithms that calculate the location, the magnetic moment size and moment orientation of the detected target. Target moment information can be used as an aid to distinguish UXO targets from clutter. MUDSS also uses data fusion techniques to further reduce clutter, detecting non-buried targets both magnetically and acoustically at the same location.

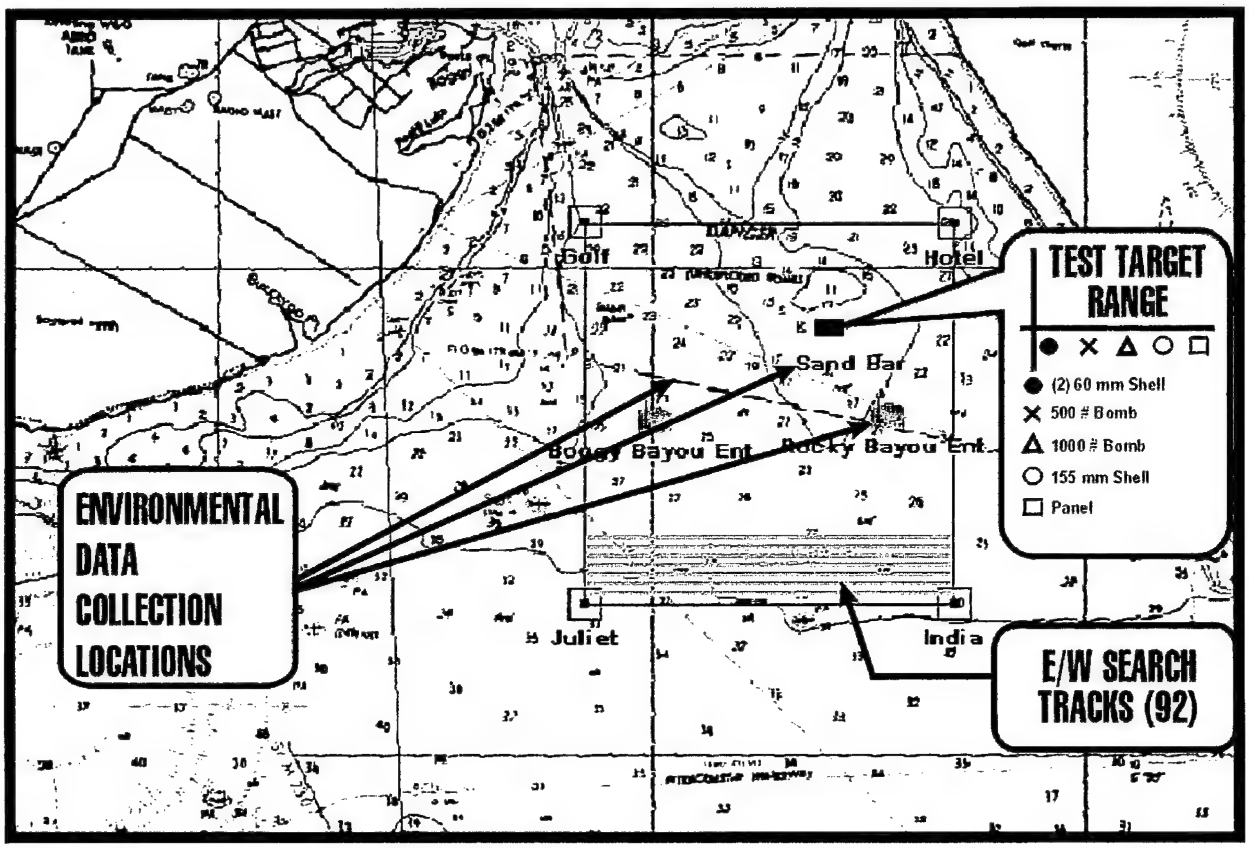

FIGURE 36. MUDSS TECH DEMO PLANNING

The MUDSS survey plan was to return and reacquire the non-buried UXO targets at the end of each test day and collect an EOID image of each reacquired target to determine whether the detected target is UXO. Buried UXO targets, detected only by the magnetic sensor, would require diver confirmation. Diver confirmation tests were scheduled for the end of the search phase. Divers were to investigate the bottom area at the GPS coordinates of potential UXO targets and swim a search pattern using a hand-held magnetic sensor to relocate the target.

As each potential UXO target was relocated with the hand-held sensor, the divers were to probe the bottom area using a rod to confirm target presence. For buried targets the plan was for divers to take soil samples near buried targets. The samples would be chemically analyzed later by JPL to determine the presence of trace explosives, a clear indicator that the target is UXO.

The MUDSS survey plan anticipated path widths of 25 m during the acoustic/magnetic search and for tow speeds of six to eight knots the survey of the two square nautical mile CB site was to be completed in five days.

MUDSS TECH DEMO RESULTS

MUDSS was tested at the CB test site during a six-day period from 19-24 November 1998. Additional tests using Navy divers to inspect suspected UXO targets were conducted on several occasions in January, April, June and November 1999.

Figure 37 shows the MUDSS towed vehicles with sensors installed during dockside testing prior to a test deployment.

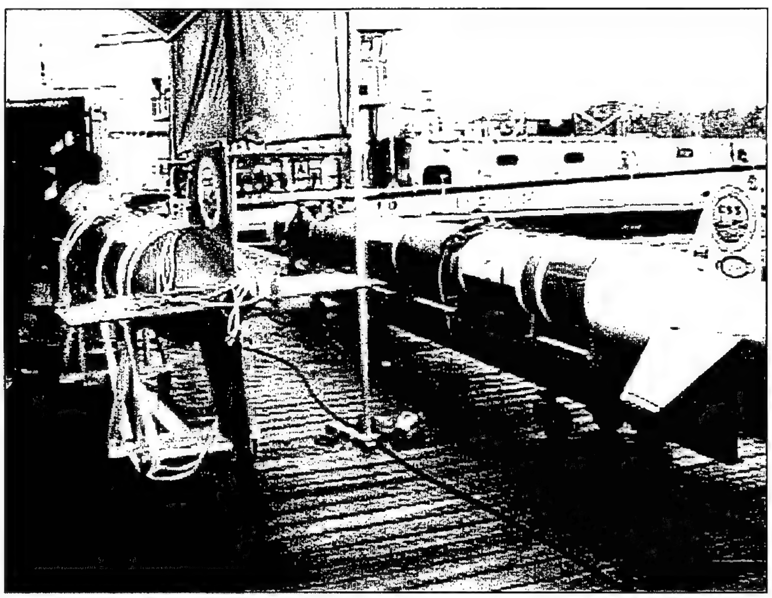

FIGURE 37 MUDSS VEHICLES WITH SENSORS INSTALLED

Figure 38 shows the *PSC8* boat towing MUDSS during an evolution to the test site. The differential GPS sensor located in the float is visible.

SVP measurements taken at several site locales showed that there was saltwater intrusion in the bay due to fresh water runoff. Saltwater intrusion caused an abrupt change in sound velocity near mid-depth and limited acoustic performance of SeaBat and SAS sensors. Beam attenuation coefficient measurements showed that visibility near the bottom was poor. With these environmental conditions, MUDSS sensors were operated ten feet above the bottom during the entire survey.

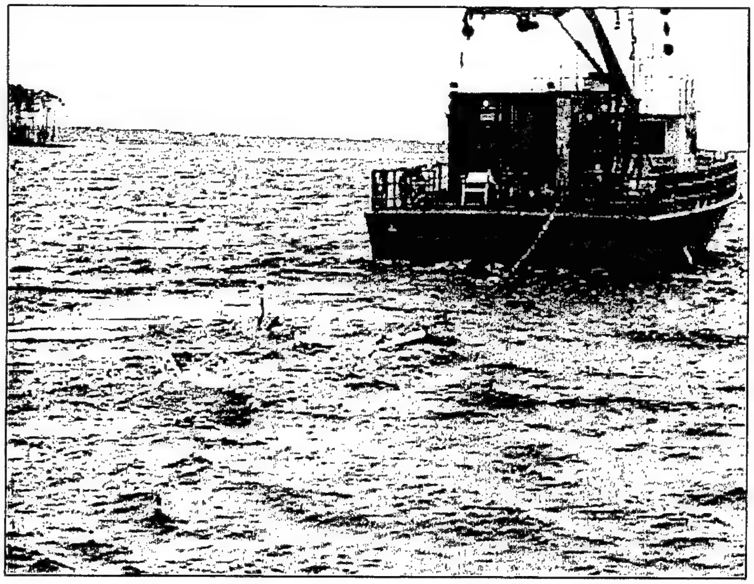

FIGURE 38. PSC-8 TOWS MUDSS TO TEST SITE

The majority of the 19-24 November test period was dedicated to surveying the designated two square nautical mile area for potential UXO. Target location was estimated from sensor position as determined by a GPS sensor trailing on the surface directly above the active tow body, the first towed vehicle. Data from the target test runs showed that the surface GPS sensor was directly above the towed depressor with errors of a meter or less. The magnetic sensor was in the second vehicle 75 ft (23 m) behind the depressor, and detected magnetic target positions were adjusted for the separation distance between the two towed vehicles.

TD Acoustic Imaging Results

Figures 39-42 are a series of acoustic image survey results from the HF/LF SAS during the track runs. Figure 39 displays HFSAS acoustic data as seen by the MUDSS operator during a search run through the test target field. In Figure 39 the tow vehicle and acoustic sensors are on the left side, and the operator observes reflected acoustic energy as a function of distance to the right. The SAS range is 15-138 ft (4.6- 42 m), and the images generated are at resolutions of the order of 1 cm x 1 cm. MUDSS includes HF and LF SAS sensors that project to both sides of the towed vehicle, but only results from one side are shown in Fig 39.

The CB search area was divided into 92 East-West tracks with track spacing of approximately 25 yds (23 m) that provided for overlapping SAS swath widths of near 80%. The search area was covered in an every-other-track pattern until all tracks had been traversed.

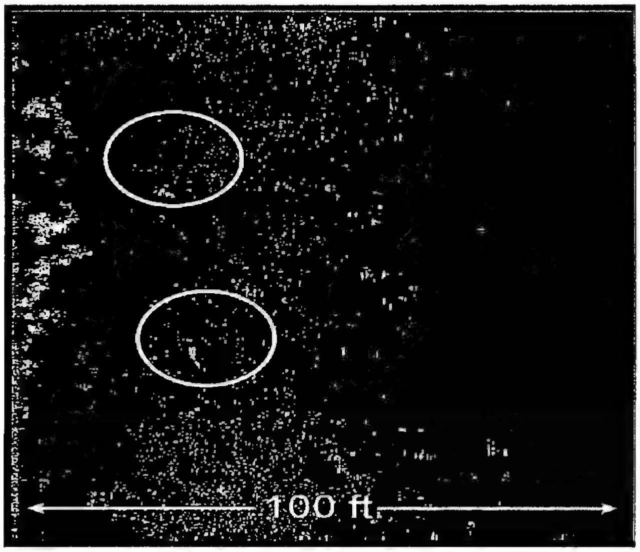

FIGURE 39. ACOUSTIC IMAGE OF TEST TARGET FIELD

The HF SAS data of Figure 39 from the target test area show that acoustic images of targets are difficult to identify except by the trained eye of an experienced operator. The acoustic images of the larger test targets, the 500-lb (227 kg) bomb and the 1000-lb (454 kg) bomb, are visible as a combination of highlights and shadows reflecting from the targets. The acoustic image of the 155-mm howitzer is more difficult to identify and the two 60-mm shells are not visible. Figure 39 also shows icons from the magnetic sensor data results that identify the positions of the two larger magnetic targets. Magnetic target localization results help prompt the operator to note potential acoustic UXO images.

The HF SAS image data of Figure 39 also shows other acoustic highlights that are rejected as targets by a knowledgeable operator who recognizes the characteristics of false targets. For example, highlights at far ranges often are due to spurious reflections and do not show the shadows expected from real targets.

Figure 40 shows both HF and LF SAS images of a 500-lb (227 kg) bomb taken during a survey run through the test area. In Figure 40 the scale is magnified by a factor of four from Figure 39, making it easier to see the shadow to the right of the target highlights in the HF data. The shadow is not visible for the LF images and in fact the highlights from the LF image are much less visible.

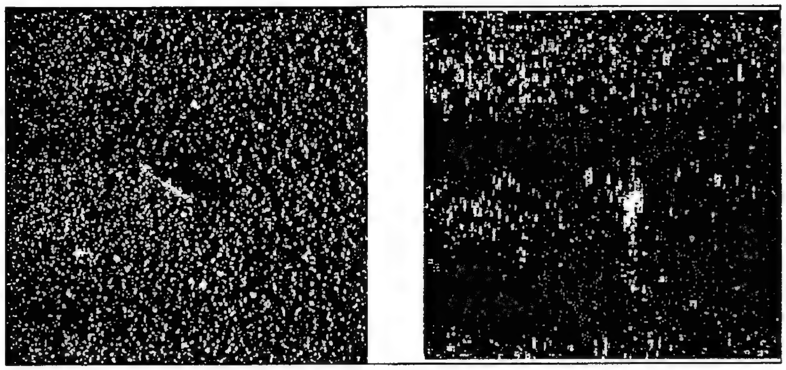

FIGURE 40. HF (left)/LF (right) SAS IMAGE OF 500-LB BOMB TEST TARGET

During the CB survey tests a large number of potential acoustic targets were detected. As expected, the operator was aided by using the magnetic target detection as a prompt. During the testing period only three targets were detected during the survey runs that displayed both the acoustic image and magnetic detection results consistent with a potential 500-lb (454 kg) UXO. (Subsequent reexamination of acoustic images several months after the survey identified five additional acoustic/magnetic targets.)

Figures 41 through 43 show the HF and LF SAS images of three detected targets designated T3, T4 and T5. The images in Figures 41-43 are also expanded by a factor of four from Figure 39 to permit detailed operator inspection. HF and LF images of T3 are shown in Figure 41, T4 in Figure 42, and T5 in Figure 43. Note the images from T4, Figure 42, exhibit the straight-line edges of a man-made target. Target T4 was the most promising candidate detected during the survey that had a high potential of being a proud UXO located at the sea bottom interface.

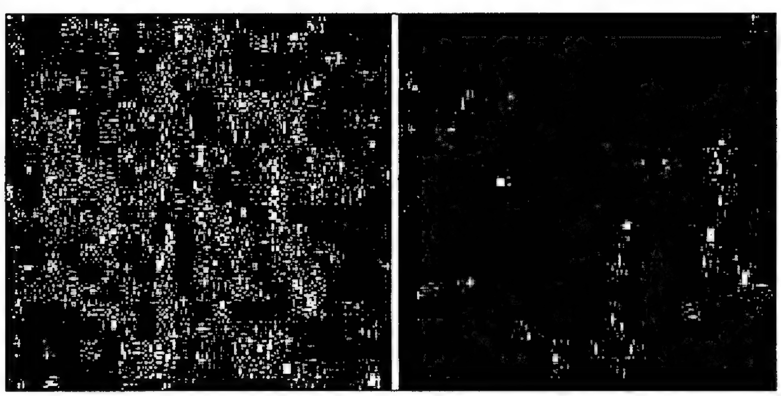

FIGURE 41. HF (left)/LF (right) SAS IMAGES OF TARGET T3.

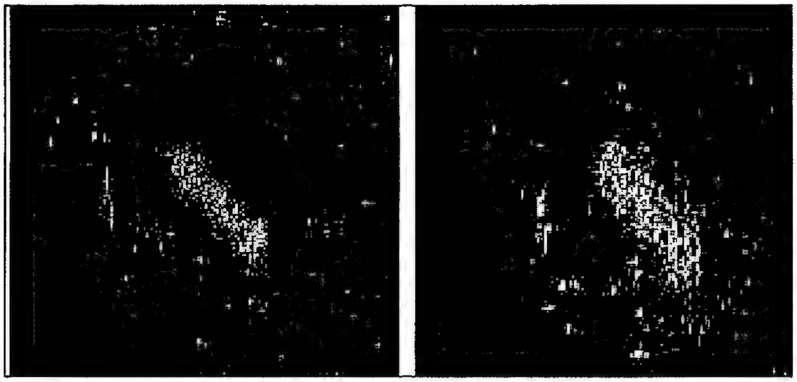

FIGURE 42. HF(left)/LF(right) SAS IMAGES OF TARGET T4

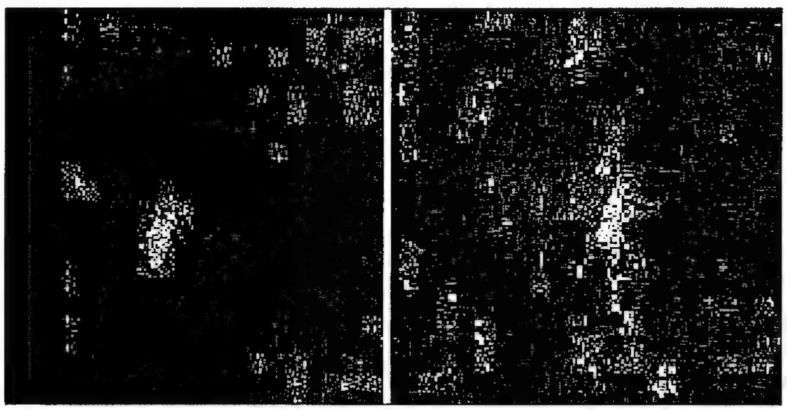

FIGURE 43. HF(left)/LF(right) SAS IMAGES OF TARGET T5

During the CB survey several targets of opportunity were detected. Figure 44 shows the HF SAS images of a boat (middle of Figure 44) and a trawler (top of Figure 44) that were observed near the boundaries of the survey area. Images from these large targets are distinct and include shape data of the targets. A long pipe was also detected on the fringe of the survey area. Images of the pipe are not included in this paper. The targets of opportunity were much larger than UXO targets.

FIGURE 44. HF SAS IMAGE OF BOAT AND TRAWLER

TD Magnetic Detection and Localization Results

The MUDSS magnetic detection algorithm calculates target position, moment size and moment orientation from the magnetic gradiometer data. In addition, MUDSS also calculates a confidence level, □, to estimate the quality of the magnetic target results. The confidence level, □, calculates the ratio of the detected target dipole model energy to energy in the ambient magnetic noise background. MUDSS magnetic measurements on the test target field established that a confidence level □> 0.4 was required for good target localization. Thus MUDSS established 0.4 as a confidence level threshold for magnetic localization during the survey.

MUDSS magnetic localization accuracy was analyzed using the localization results from seven different search runs over the test target field. The standard deviation of target location for the 500-lb (227 kg) bomb and 1000-lb (454 kg) bomb were calculated. The standard deviation equaled +/- 3 meters for the 500-lb (227 kg) bomb and +/- 2 meters for the 1000-lb (454 kg) bomb. Also the average calculated position for the 500-lb (227 kg) and 1000-lb (454 kg) bomb was within a standard deviation from the coordinates recorded during test target deployment.

A total of 488 well-localized magnetic targets with confidence levels > 0.4 were detected during the survey. 193 targets were located with magnetic moment magnitude in the correct range for a UXO target - 1×10^4-1×10^5 gamma-ft^3. A number of targets were magnetically detected more than once during repeat track runs over the test target field. Targets located within 5-10 ft (1.5-3 m) of each other were considered multiple detection of the same target and were not double counted in the 193 targets. The number of potential UXO targets was reduced from 193 to 157 by applying a filter requiring that target magnetic moment vector be primarily an induced moment with significant component projected along the earth's magnetic field direction. The magnetic data from these targets are presented in Appendix E.

Figure 45 is a map of the survey area with the location of each of the 157 potential UXO targets designated by a dot. A number of magnetic targets are highlighted. Targets T1 and T2 are the 500-lb (227 kg) and 1000-lb (454 kg) bombs located in the test target area. Other magnetic targets, designated T3-T20, were selected for separate inspection by Navy divers to confirm which unknown targets were UXO. Table 5 lists the initial MUDSS survey results highlighting Targets 1 through 20. Targets T3 through T20 were selected as the most likely targets to be confirmed a UXO. Targets T3, T4 and T5 were selected because they were detected both acoustically and magnetically and thus were prime candidates for being proud or very shallow buried UXO targets. Targets T6-T20 included a group of UXO-sized targets with the highest confidence levels, α, all above 3.0. Additional target information is presented in tabular form. Table 5 lists the target position relative to the bottom for each selected target as calculated from the magnetic data with the bottom as 0 ft (0 m). Accuracy of this target depth is estimated at approximately one foot (30 cm). Data from Table 5 indicate that the three acoustic and magnetic-detected targets are near the bottom (0) or buried very shallow. Note that most of the remaining bomb-sized UXO targets are buried a foot or more below the bottom.

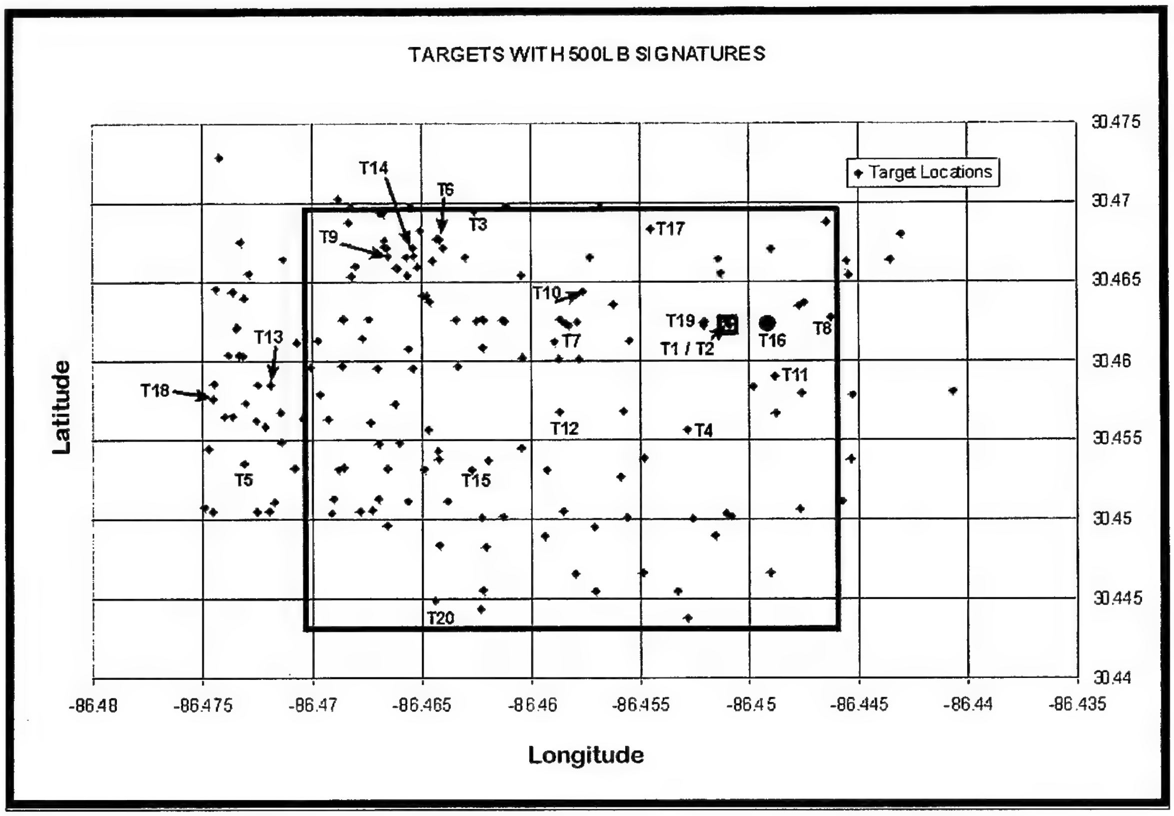

FIGURE 45. INITIAL MUDSS SURVEY RESULTS

TABLE 5. INITIAL MUDSS SURVEY RESULTS

Target #	High magnetic confidence/UXO	Target Depth (mag) (ft)	Acoustic +mag signature	Diver Investigated	Diver Reacquired	Diver IDed	Chemical Sample
T1	X	0	X	-	-	-	-
T2	X	0	X	-	-	-	-
T3	X	0	X	X	-	-	-
T4	X	0	X	X	-	-	-
T5	X	0	X	X	-	-	-
T6	X	3	-	X	-	-	-
T7	X	1	-	X	-	-	-
T8	X	0	-	X	-	-	-
T9	X	7	-	X	-	-	-
T10	X	1	-	X	X	X	-
T11	X	0	-	X	-	-	-
T12	X	2	-	X	-	-	-
T13	X	0	-	X	X	X	B1
T14	X	7	-	X	-	-	-
T15	X	2	-	X	-	-	-
T16	X	0	-	X	X	X	A2
T17	X	3	-	X	-	-	-
T18	X	2	-	X	-	-	-
T19	X	1	-	X	X	-	B6
T20	X	7	-	X	-	-	-

Since the buried targets cannot be detected acoustically nor optically, MUDSS plans were to use Navy divers to verify potential UXO targets. Divers investigated eighteen targets identified in Table 5. Diver tests were conducted in January 1999 and April 1999. The diver reacquisition tests were originally scheduled to be performed concurrent with the MUDSS survey but inconsistencies in MUDSS magnetic and acoustic target localization results were not resolved until a few weeks after the survey.

The divers used two different hand-held magnetic sensors during the target reacquisition tests. In January the divers used a MK 26 ordnance locator and had partial success reacquiring four targets, all buried, using concentric circle search techniques starting at the DGPS coordinates of each MUDSS detected target. Targets located by divers included a round steel plate (T10), a six-inch (15.5 com) diameter pipe section three feet (one meter) long, (T13), a cylindrical object (T16), and an unidentified magnetic object (T19). The divers detected the unidentified target magnetically but they could not locate it by probing with a rod. Chemical sediment samples were taken at three sites. The divers were not able to reacquire a number of other MUDSS-detected targets. For a number of these target sites the diver Mark 26 magnetic sensor performed erratically. A number of the targets not reacquired were at sites with thick silty bottoms where the distance to the sand bottom was not well known. Additional divers reacquisition tests were performed in April 1999 using the Mark 25 hand-held magnetic sensor. Calibration tests performed by divers at CSS in late January indicated that the Mark 25 was a more reliable diver magnetic sensor. No additional targets were located during the April tests but one buried target, T16, was partially excavated and appeared more like a UXO target.

During the April tests the Mark 25 performed consistently. The divers reacquired target T16 during a third dive in June 1999. T16 was excavated by hand and was identified as a 500-lb (113 kg) bomb. Subsequent completed excavation by divers in November 1999 revealed that T16 had bomb-like shape and features but T16 was not a bomb.

EOID Sensor Results

The EOID sensor was used selectively when test conditions indicated that EOID images could be obtained. EOID images were obtained for the larger test targets. Figure 46 shows the EOID images of the 500-lb (454 kg) test target bomb, Figure 47 the 1000-lb (454 kg) test target bomb, and Figure 48, the Aluminum test panel. Visibility was so poor that it took several track passes through the test target area to obtain these images. Figure 49 is an EOID image of a trawler, a target of opportunity located on the fringe of the Choctawhatchee Bay survey area. The EOID sensor operated as expected but was limited in imaging range capability by the low visibility water.

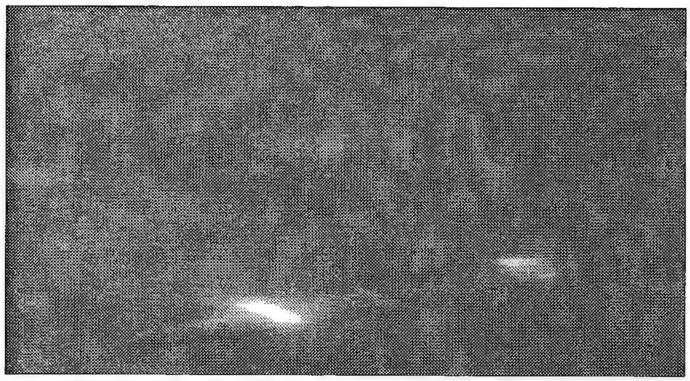

FIGURE 46. EOID IMAGE OF 500 LB (227 KG) TEST TARGET

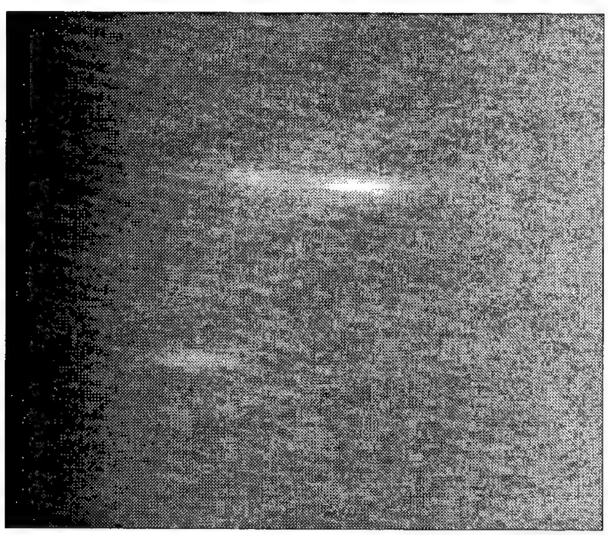

FIGURE 47. EOID IMAGE OF 1000 LB (454 KG) TEST TARGET

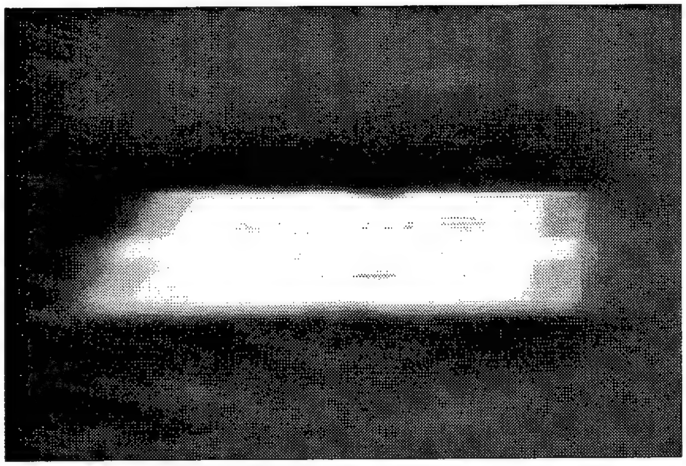

FIGURE 48. EOID IMAGE OF AL TEST PANEL

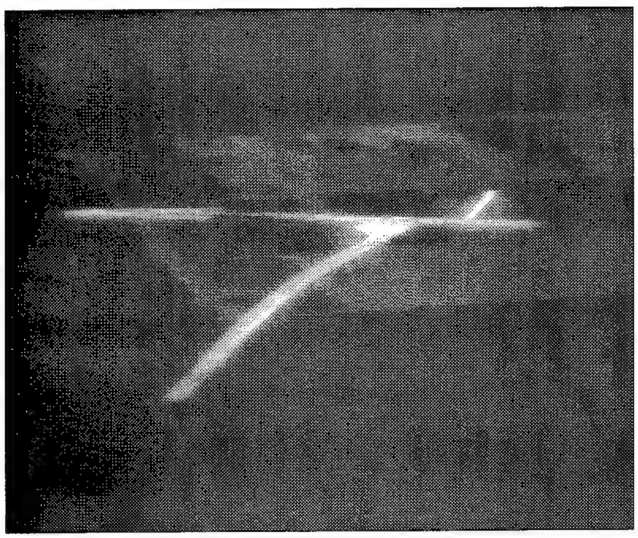

FIGURE 49. EOID IMAGE OF TRAWLER

Additional MUDSS Results

All of the MUDSS visualization features were not available during the Choctawhatchee Bay survey. Results that became available several months after the initial Choctawhatchee Bay tests and analysis demonstrate some of the planning and display features of Melian and led to additional testing and analysis. Figure 50 shows the MUDSS Melian display that graphically presents the search tracks that were planned and executed during the five days of MUDSS surveying at Choctawhatchee Bay. Completed tracks are based on the MUDSS search coordinate data from the GPS sensor trailing above the MUDSS towed vehicle. A total of 92 East-West tracks were performed along the prescribed search paths.

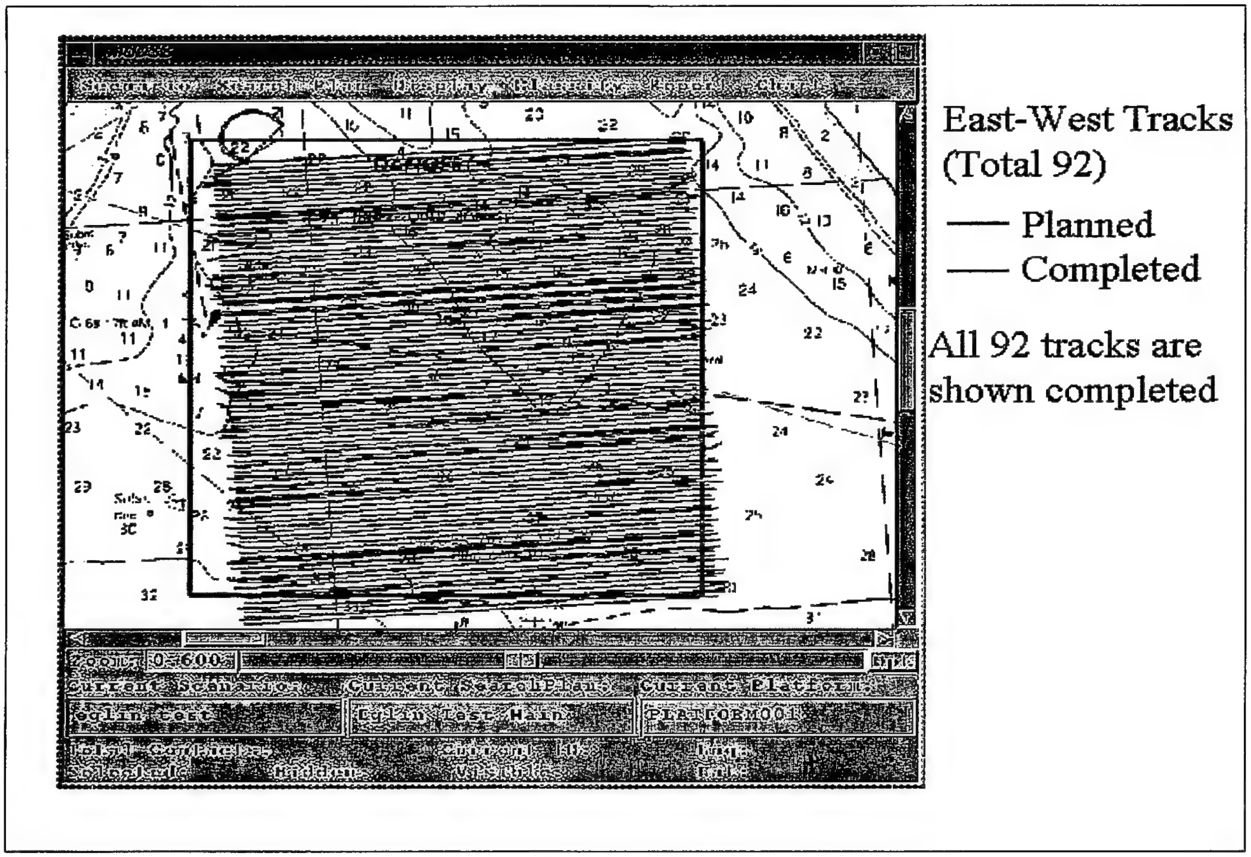

FIGURE 50. DISPLAY OF MUDSS PLANNED AND COMPLETED SEARCH TRACK FROM THE TECHNOLOGY DEMONSTRATION

Additional systematic analysis of MUDSS acoustic and magnetic data was performed several months after the Choctawhatchee Bay tests were completed, when Melian was available for use in the analysis. An operator experienced in evaluating SAS images performed an analysis of the MUDSS HF and LF SAS acoustic image data from the 92 MUDSS tracks. The operator selected approximately 150 acoustic contacts that were target-like. Figure 51 shows an example of the HF and LF image of an object declared a contact by the operator. A listing of the acoustic contacts from this analysis is presented in Appendix E. Each acoustic contact selected by the operator was assigned a subjective target confidence level between one and five, a five being the strongest confidence that the contact was a target.

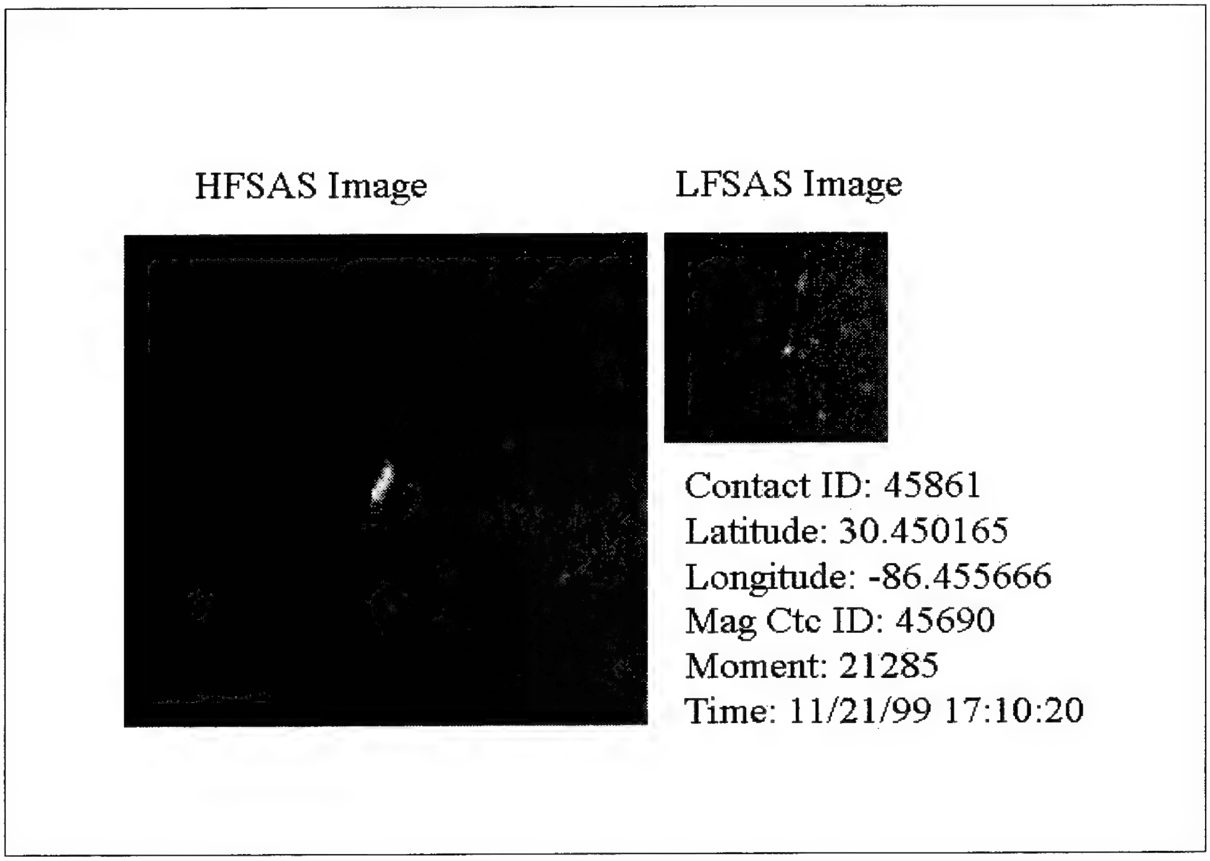

FIGURE 51. HF AND LF SAS IMAGE OF ACOUSTIC CONTACT FROM MUDSS TRACK

Figure 52 is a plot of the high confidence (>3) acoustic contacts detected during the MUDSS TD as plotted in the CB search area. Figure 53 is a plot of selected magnetic targets detected during the 92 search tracks. The magnetic targets selected and plotted in Figure 53 had a high confidence level (above 0.4 as mentioned above) and an appropriate target moment size and moment orientation. Figure 54 is a plot of the acoustic targets that had a selected magnetic target within five meters and within ten meters of an acoustic contact. Excluding the test targets, seven targets are identified as both acoustic and magnetic target locations. These seven targets were not identified in the initial MUDSS analysis (see Table 5 above) and presented promising prospects of UXO targets that were either on the surface bottom or buried shallow.

The new data was viewed as an opportunity to successfully reacquire additional targets from the CB survey and potentially validate one or more practice bomb targets. The decision was made to use revisit the CB site in November 1999 and assign Navy divers to inspect these sites using the Mark 25 hand-held magnetic sensor. It was also an opportunity for divers to revisit the site T16 where divers had partially uncovered and identified the bomb-shaped cylinder in June 1999. Note that T16 would not have been detected acoustically during the November 1998 survey if it were buried much below the bay bottom.

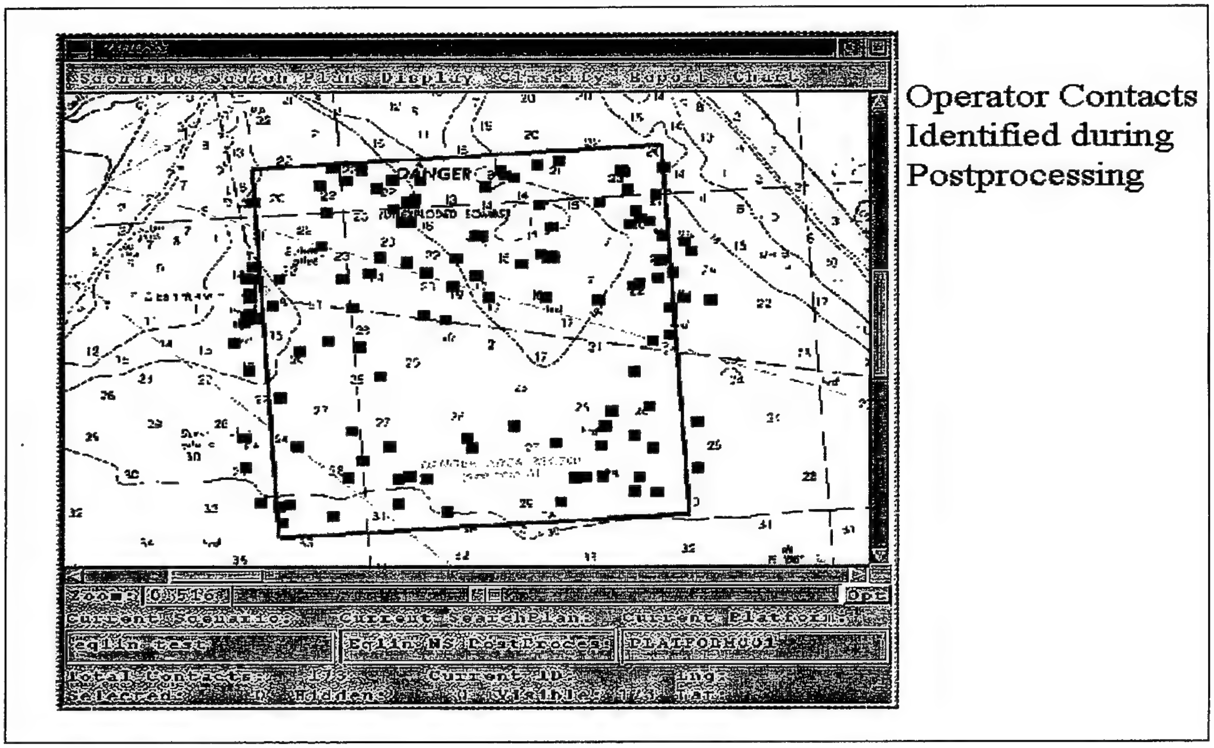

FIGURE 52. PLOT OF ACOUSTIC CONTACTS IN CHOCTAWHATCHEE BAY SEARCH AREA

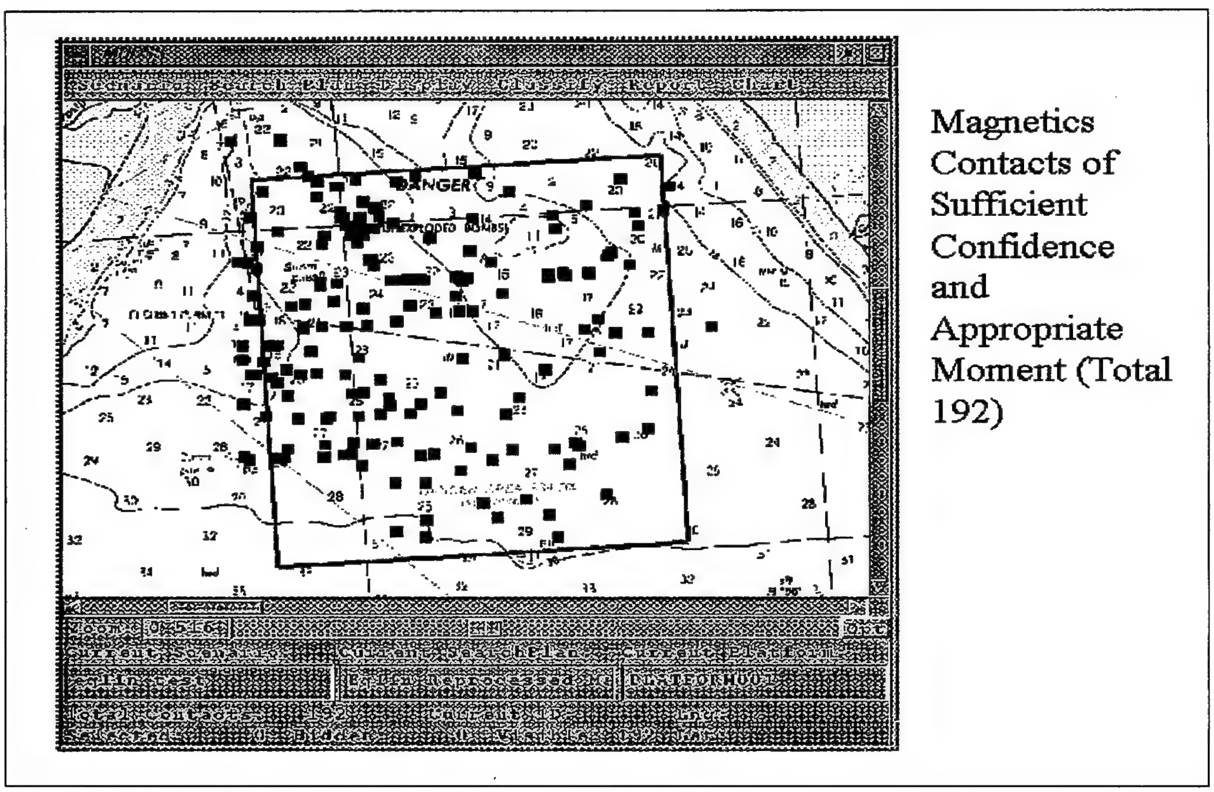

FIGURE 53. PLOT OF SELECTED MAGNETIC CONTACTS IN CHOCTAWHATCHEE BAY SEARCH AREA

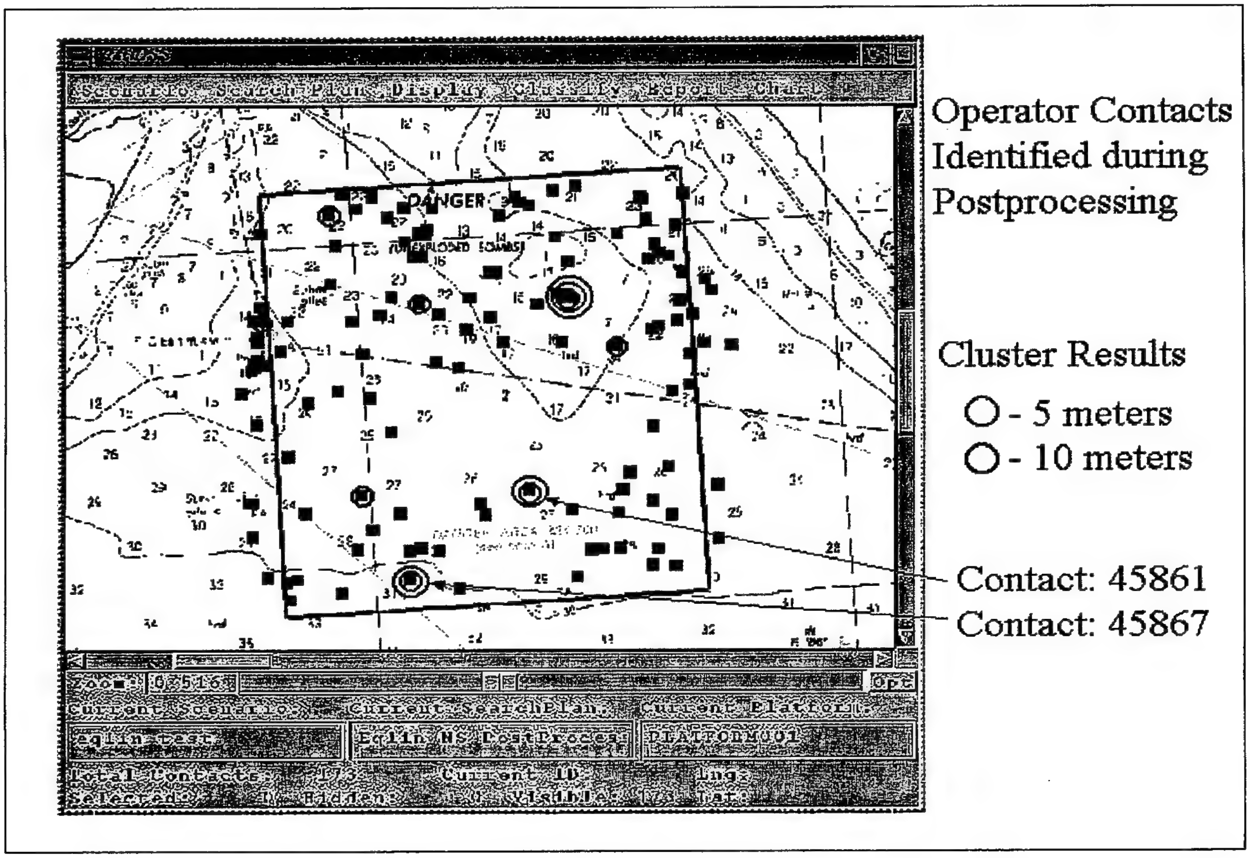

FIGURE 54. PLOT OF COINCIDENT MAGNETIC AND ACOUSTIC CONTACTS IN CHOCTAWHATCHEE BAY SEARCH AREA

Navy divers revisited the CB site on 9 November 1999 and conducted a search of the sites identified above. DGPS was used to relocate the target sites. The divers relocated the trawler wreck site within a few meters of the location identified during the November 1998 tests. Divers proceeded to the T16 site and conducting a circular search with the Mark 25 magnetic sensor relocated the T16 target within a meter or two of its coordinates. T16 was found buried a foot beneath a sandy bottom. Upon excavating, the divers determined that the T16 target was cylindrical and approximately the dimensions of a bomb, but the object was not a bomb. The detected object was covered with barnacles and best estimates were that it was a propane tank.

The divers proceeded to other acoustic/magnetic target locations shown in Figure 54 and conducted magnetic searches with the Mark 25 sensor. The divers were unable to relocate any additional targets while inspecting five of the identified sites. The first four sites were in areas where the bottom had a thick layer of silt. Diver inspection revealed that the silt in these locations was greater than three feet (one meter) - an arms length. The divers were unable to contact the sand bottom when they reached through the silt. The divers were not able to relocate a target at the fifth site. The fifth site had a clear, sandy bottom but the divers did not detect a magnetic target with the hand-held magnetic sensors.

Results from the latest diver relocation efforts demonstrate that the target verification process is more difficult than was anticipated. Navy diver magnetic detection equipment appears marginally capable of detecting and relocating targets that are in deep silt or buried very deeply. When the Navy divers conduct a magnetic search in a silty area, the sensor is held well above the bottom in order to avoid stirring the silt (and losing visibility). Target/sensor separation due to the thickness of the silt, diver search techniques, and target burial may combine to exceed the detection distance for the Mark 25 against bomb-sized targets. Additional analysis is being performed to assess the target/sensor range.

CONCLUSIONS

Analysis of the MUDSS data yields the following conclusions:

1. MUDSS identified 157 targets with (1) a high level of confidence of being a 500-lb (227 kg) UXO bomb or magnetic, bomb-sized target and (2) magnetic moment aligned in the direction of the earth's field.

2. Eighteen of these 157 targets were selected as the best targets for potential diver verification. Using hand-held magnetic sensors, divers were able to excavate and confirm:
    - One target shaped and sized like a 500-lb (227 kg) UXO bomb (subsequently found to not be a bomb).
    - Two of the UXO-like targets were non-UXO (a manhole cover and a pipe).
    - All other targets investigated were not confirmed due to burial depth or inability to reacquire via the hand-held sensor.

3. Only seven of the suspected UXO targets had possible UXO-like acoustic signatures. Divers were not able to verify any of the seven as being UXO. A primary reason for the low acoustic UXO-like hits was the fact that all of the 500-lb (227 kg) bombs were likely buried in the Choctawhatchee Bay test environment.

4. The poor visibility environment, combined with the likelihood that the UXO was buried, resulted in no Electro-Optic imagery of actual UXO.

5. The chemical analyses for trace explosives from samples taken near a small set of the suspected 500-lb (227 kg) UXO bombs were negative. In one case the target was located, excavated and determined not to be a UXO. Chemical analysis is consistent. Based on feasibility testing, chemical sampling still offers a potentially effective technique to confirm UXO detection.

6. The Choctawhatchee Bay tests confirmed the need for the MUDSS multiple sensor approach; for very difficult underwater environment, different phenomenological looks at potential UXO targets maximize the potential for success in surveying unknown sites.

7. The Choctawhatchee Bay survey demonstrated that the MUDSS system can be effectively used to map the location of suspected WWII UXO. The entire two square nautical mile site was surveyed during a six-day operation.

8. Additional analysis of the Choctawhatchee Bay data will permit evaluation of the effectiveness of MUDSS visualization and computer-aided detection capabilities.

9. All MUDSS features were not fully operational during the Choctawhatchee Bay survey.

10. Additional MUDSS demos are needed for a wide variety of both operational environments (water depths, bottom types, salinity, turbidity, etc.) and UXO target types.

11. Target reacquisition, identification and validation by divers is much more difficult than anticipated. An improved diver magnetic sensor can assist in UXO relocation and verification.

ACKNOWLEDGEMENTS

MUDSS development and testing was funded through SERDP under Cleanup Program Manager, C. Vogel and SERDP Technical Director, J. Marqusee. MUDSS sensors were developed under ONR sponsorship.

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APPPENDIX A

MOBILE UNDERWATER DEBRIS SURVEY SYSTEM (MUDSS) SONARS

APPENDIX A: MUDSS SONARS

Phase I tests of the Mobile Underwater Debris Survey System (MUDSS) used three different sonars, which were the low frequency Magnetic Acoustic Detection of Mines (MADOM) Synthetic Aperture Sonar (SAS), the high frequency High Performance Side Scan (HPSS) and the SeaBat, a commercial ahead-looking sonar system. For Phase II, the low frequency (LF) and high frequency (HF) SAS and the SeaBat, were used in Choctawhatchee Bay.

SYNTHETIC APERTURE SONAR

The side-scan SAS used in Phase II includes low and high frequency sonars. The low frequency 20-kHz SAS provides acoustic images of bottom or shallow buried targets by penetrating the bottom with low frequency acoustic energy. The high frequency 180-kHz SAS provides images where targets are identifiable as bright images with a characteristic shadow, producing additional shape information. For the LF SAS the target has only a bright image with no shadow, because the sonar works at sufficiently low frequency to penetrate the bottom and detect buried objects. Both sonars, are shown in Fig. A-1.

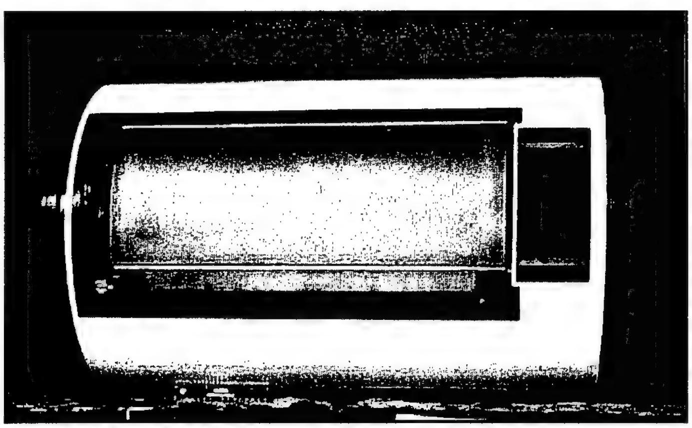

FIGURE A-1. PHASE II HF AND LF SAS SONAR

The SAS used in Phase II of MUDSS is a double-sided side scan sonar system housed in a 3-ft long by 21-in diameter shell section (all sections in the underwater towed vehicles are 21-in diameter, sealed, and Mk 48 joint band compatible). The SAS section houses the LF and HF side-looking projectors and arrays and all of the analog and digital electronics of the system, (i.e. power conversion, transmitter, receiver, data acquisition

[analog-to-digital converters, data multiplexers, etc.], timing circuitry, data telemetry, and system status and control). The tow body power distribution system provides the SAS with about 750 W of power at 28 V DC, interfaced to the SAS is a Doppler sonar, which is used to control the pinging of the SAS. The Doppler also provides height and speed information to the electro-optic identification (EOID) sensor, which it requires in automated operation mode. The SAS powers and controls the Doppler unit.

Fiber optic wires carry SAS system status, control, and data telemetry between the SAS and the 10 billion floating point operations per second (gigaflops) embedded real-time processing system (GEM) computers on the active tow body. GEM's principal function in the MUDSS system is to motion compensate and beamform the SAS stave data (it is these operations that require GEM's enormous computing capacity), producing a continuous waterfall image that it sends topside.

The LF SAS parameters are given in Table A-1. Each receive signal from the staves is preconditioned before analog-to-digital (A/D) conversion by preamplifiers, Three-pole Bessel bandpass filters, and time-varying gain (TVG) amplifiers. All LF SAS processing within GEM is for continuous wave (CW) pulses, although the LF SAS is capable of generating frequency modulation (FM) sweeps.

Functionally, analog signal conditioning in the HF SAS is done similarly to the LF SAS. The exception is that real bandwidth sampling is used to sample the HF signals at a rate of 240 kHz. The HF SAS parameters are given in Table A-2. All HF SAS processing within GEM is for CW pulses, although the HF SAS is capable of generating FM sweeps.

TABLE A-1. LF SAS PARAMETERS

PARAMETER	VALUE
Center frequency	20 kHz
Theoretical azimuth resolution	3" (7.5 cm)
Theoretical range resolution	3" (7.5 cm)
Theoretical range	44 yds (40 m) at 8 kts
Array length of receiver	21" (53 cm)
Hydrophone horizontal beamwidth	1.78 rad (102 deg)
Hydrophone length	0.5 wavelengths (1.5", 3.8 cm)
Number of staves	14 per side (2 for motion compensation)
Hydrophone vertical beamwidth	0.44 rad (25 deg)
Hydrophone height	2 wavelengths (6", 15 cm)
Projector horizontal beamwidth	1.05 rad (60 deg)
Projector length	1 wavelength (3", 7.6 cm)
Projector vertical beamwidth	0.55 rad (32 deg)
Projector height	2 wavelengths (6", 15 cm)
Maximum source level	212 dB
Depression angle (proj and rec)	5 deg
Bandwidth	10 kHz

TABLE A-2. HF SAS PARAMETERS

PARAMETER	VALUE
Center frequency	180 kHz
Theoretical azimuth resolution	1" (2.5 cm)
Theoretical range resolution	1" (2.5 cm)
Theoretical range	44 yds (40 m) at 8 kts
Array length of receiver	22" (55.8 cm)
Hydrophone horizontal beamwidth	0.14 rad (8.4 deg)
Hydrophone length	6.1 wavelengths (2", 5.1 cm)
Number of staves	11 per side (2 for motion compensation)
Hydrophone vertical beamwidth	0.44 rad (25 deg)
Hydrophone height	2 wavelengths (.67", 1.7 cm)
Projector horizontal beamwidth	0.14 rad (8.4 deg)
Projector length	6.1 wavelengths (2", 5.1 cm)
Projector vertical beamwidth	0.44 rad (25 deg)
Projector height	2 wavelengths (0.67", 1.67 cm)
Maximum source level	214 dB
Depression angle (proj and rec)	5 deg
Bandwidth	30 kHz

The speed-dependent maximum ranges of the LF and HF SAS are both 40-m at eight knots. The effective maximum ranges are often reduced in very shallow water operation by multi-pathing and/or by target burial.

SEABAT

A commercially available SeaBat sonar (Fig, A-2) provided a forward look capability for target detection, reacquisition, and/or obstacle avoidance for both Phase I and Phase II of MUDSS. SeaBat targets are depicted as a bright spot in the sonar image.

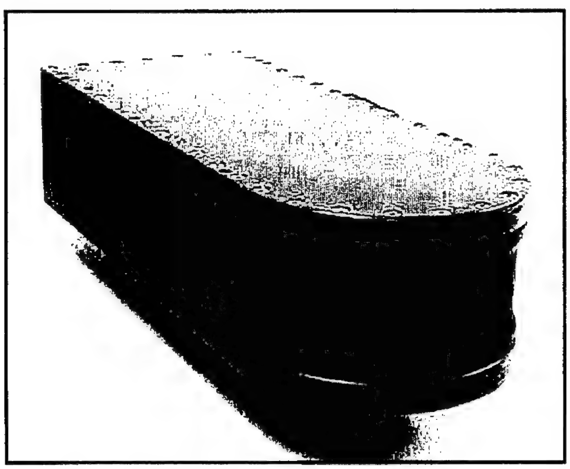

FIGURE A-2. SEABAT SONAR

The SeaBat sonar is used for target reacquisition and is housed in the nose section of the dead weight depressor for Phase I, and in the nose section of the active depressor for Phase II. The SeaBat has a range of 100 m and insonifies 15-deg vertically by 90-deg horizontally immediately in front of the active tow body. Image resolution is 1.5-deg horizontally and 15-deg vertically. The operating frequency is 455 kHz.

HIGH PERFORMANCE SIDE-SCAN SONAR (HPSS)

The HPSS (see Figure A-3) and the MADOM SAS were used only in Phase I of MUDSS. The HPSS is a one-meter long array containing ten 10-cm long elements. Because of limitation of the MUDSS Phase I sonar data link, only five of the ten elements were used. Specifications for the HPSS, along with specification for the other sonar used in Phase I are listed in Table A-3.

TABLE A-3. SPECIFICATIONS FOR PHASE I SONARS

Sonar Specification	**HPSS**	**MADOM SAS**	**SeaBat**
Sensor Type	Synthetic aperture side-looker	Synthetic aperture side-looker	Ahead-looker
Center Frequency	600 kHz	16.5 kHz	455 kHz
Azimuth Resolution	5 cm	7.5 cm	1.5 deg
Range Resolution	20 cm	7.5 cm	5 cm
Maximum Speed	5 kts	5 kts	7 kts
Range at 5 knots	4 - 35 m	0.6 - 35 m	5 – 200 m
Receiver Array Length	40 cm	30 cm	---
Number of Beams	1	1	60 (90 deg sector)
Hydrophone Horizontal Beamwidth	1.4 deg	69.4 deg	---
Hydrophone Length	10 cm	7.5 cm	---
Number of Staves	4	4	---
Hydrophone Vertical Beamwith	13 deg	45 deg	15 deg
Projector Horizontal Beamwidth	1.4 deg	34.8 deg	165 deg
Projector Length	10 cm	15 cm	---
Projector Vertical Beamwidth	13 deg	15 deg	45 deg
Depression Angle	10 deg	5 deg	15 deg
Bandwidth	4 kHz	10 kHz	---
Sampling Frequency	64.789 kHz	64.789 kHz	---

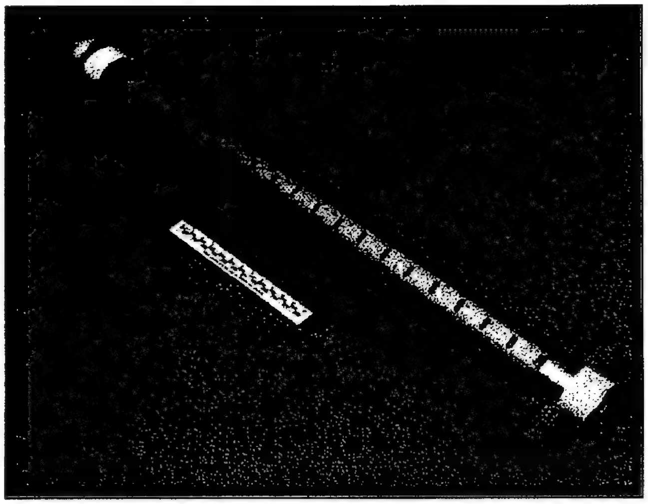

FIGURE A-3. HIGH PERFORMANCE SIDESCAN SONAR

REFERENCES:

A-1. J. T. Christoff and J. E. Fernandez "Dual Frequency Synthetic Aperture Imaging Sonar", 1998 *International Geoscience and Remote Sensing Symposium Proceedings,* Seattle, WA.

APPPENDIX B

ELECTRO-OPTIC SENSORS

data pass directly through the 10 billion floating point operation per second (gigaflops) embedded real-time processing system (GEM), which formats the signals for radio telemetry to the MilVan. All EOID processing occurs in the MilVan

The EOID's diode-pumped neodymium-doped yttrium aluminum garnet (ND:YAG) laser provides illumination at 532-nm. Laser output power is approximately 300-500 mW. For safety, the laser is automatically shut off if the sensor rolls more than 40-deg.

The EOID sensor is designed to minimize the environmental effects of backscatter and glow from the water. Its design requires that the minimum range to the target be 2.5 m. Its maximum operating range varies with environment, but is typically between five and seven optical attenuation lengths. Note that attenuation length is dependent on water quality. One attenuation length is approximately 1/c, where c is the average attenuation coefficient of the water. So, for water with an average attenuation coefficient of 0.8 m^{-1}, the maximum operating range of the EOID sensor (five to seven attenuation lengths) would be from 6.25 m to 8.75 m.

The 70-deg field of view (FOV) of the EOID sensor is centered directly beneath the sensor. The EOID swath width is approximately 2*h*tan(FOV/2) = 1.4h, where h is the height above the bottom.

The cross-track EOID image resolution (neglecting environmental effects) is dependent on height of the sensor above the target and the number of pixels in a scan line. It is given approximately as h*FOV/Npixels, where the 70-deg FOV is expressed in radians and Npixels is the number of pixels in the scan (Npixels can be selected to be 512, 1024, 2048, or 4096). This is illustrated in Figure B-2.

The along-track EOID image resolution (neglecting environmental effects) is dependent on the towing speed of the sensor and the scan rate of the sensor. It is given by v/4f, where v is the tow speed and f is the scan rate (f is continually adjustable from 500 rpm to 4000 rpm). This is illustrated in Figure B-3.

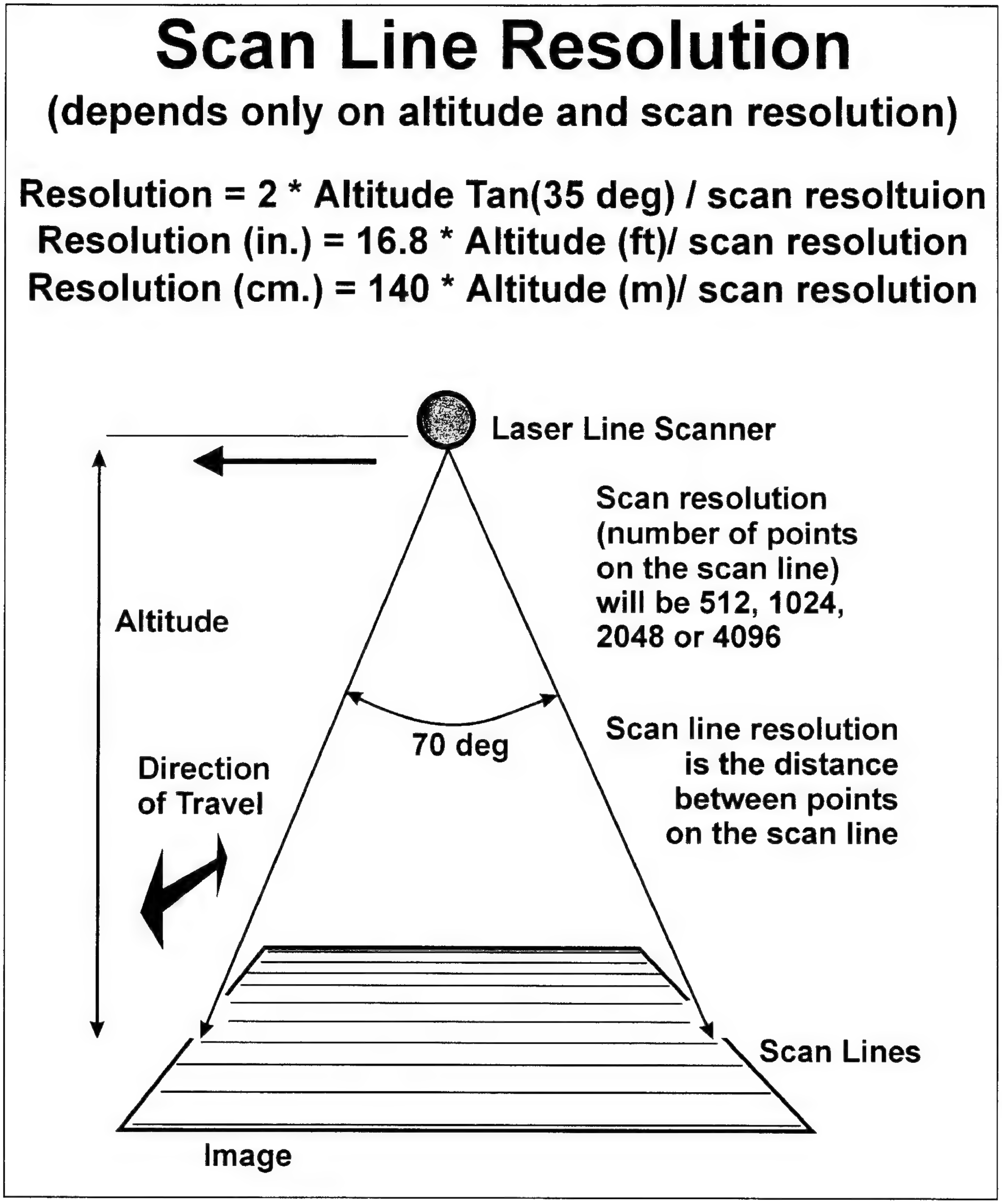

FIGURE B-5. CROSS-TRACK EOID IMAGE RESOLUTION

Forward Direction Resolution

(depends only on vehicle speed and scan motor speed)

Resolution = Vehicle Speed / (4 scan lines * rpm / 60 seconds)

Resolution (in.) = * 303.8 * Vehicle Speed (kts.) / rpm

Resolution (cm) = 1500 * Vehicle Speed (m/s) / rpm

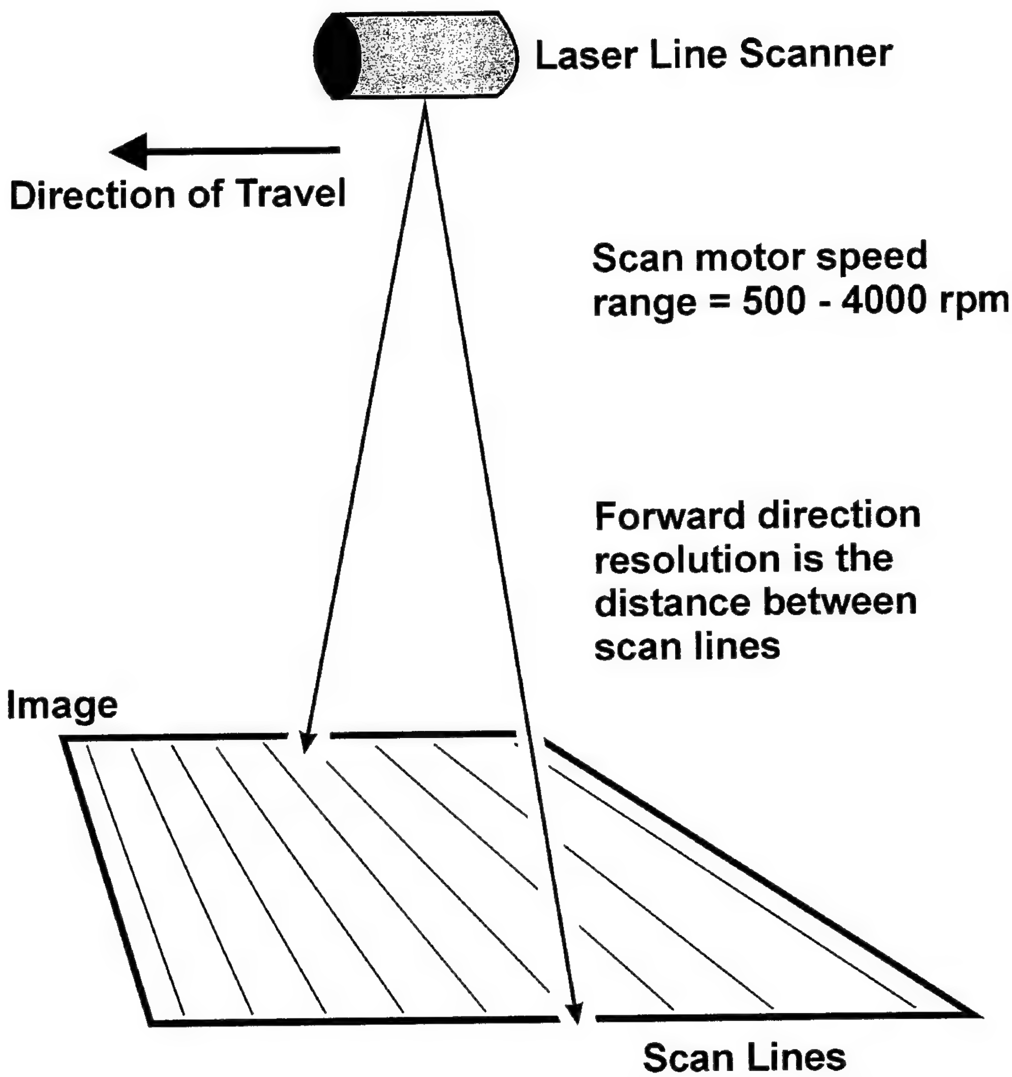

FIGURE B-6. ALONG-TRACK EOID IMAGE RESOLUTION

APPPENDIX C

MAGNETIC SENSOR

APPENDIX C: MUDSS MAGNETIC SENSOR

A cryogenically cooled, superconducting magnetic field gradiometer provided MUDSS with an unburied (proud) and buried target capability by sensing five independent target magnetic gradients which are processed to calculate the target position (range and bearing) and magnetic moment vector. The target magnetic moment, a function of the ferrous mass, provides target classification information that is a valuable complement to the shape information provided by the acoustic sensors. Gradiometer sensitivity of three pTesla/meter is achieved in Mobile Underwater Debris Survey System (MUDSS) towed operation.

The MUDSS magnetic sensor, used in Phase I and Phase II, is the Superconducting Gradiometer/Magnetometer Sensor (SGMS). The three magnetic field and five field gradient superconducting sense loops of SGMS are mounted in the cryogenic probe assembly, which is contained in a cylindrical, passive cooling dewar whose liquid helium bath outgassing keeps the sensor at superconducting temperatures. The changing supercurrents in the sense loops, which are proportional to the changing field or field gradient, are measured by means of Superconducting Quantum Interference Devices (SQUIDs). The gradiometer channels are used to detect, classify and localize magnetic targets. The magnetometer channels are used for motion compensation. The gradiometer portion of the SGMS is shown in Figure C-1.

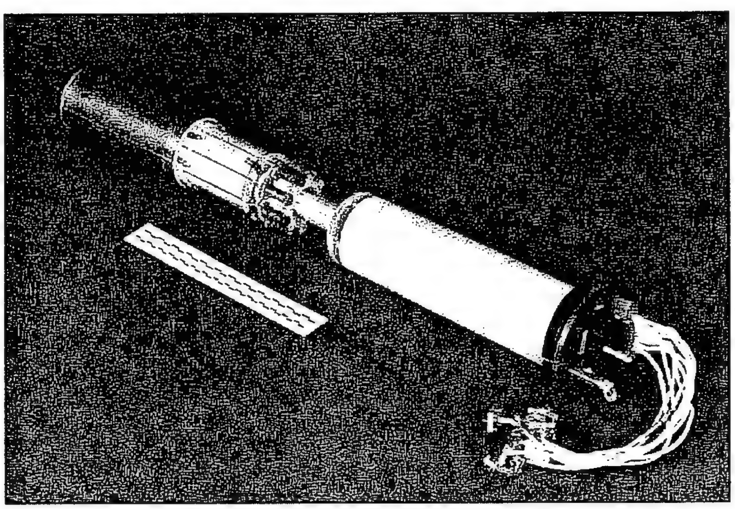

FIGURE C-1. MAGNETIC FIELD GRADIOMETER

The dewar containing the gradiometer is 45-in (114 cm) long and 13-in (33 cm) diameter. It has a maximum capacity of 15 liters of liquid helium for a hold time of three days, although the liquid helium should be replenished every day when taking the sensor out for sea tests.

Connected to the cryogenic probe assembly at the front end of the dewar is the data link electronics for the sensor (see Figure C-2). The data link consists of eight packages of SQUID electronics, anti-aliasing filters, analog-to-digital (A/D) converters, and control circuits for remote use, gain and offset control. The approximately 30 W of power required to run the gradiometer is supplied by the active towed vehicle distribution system.

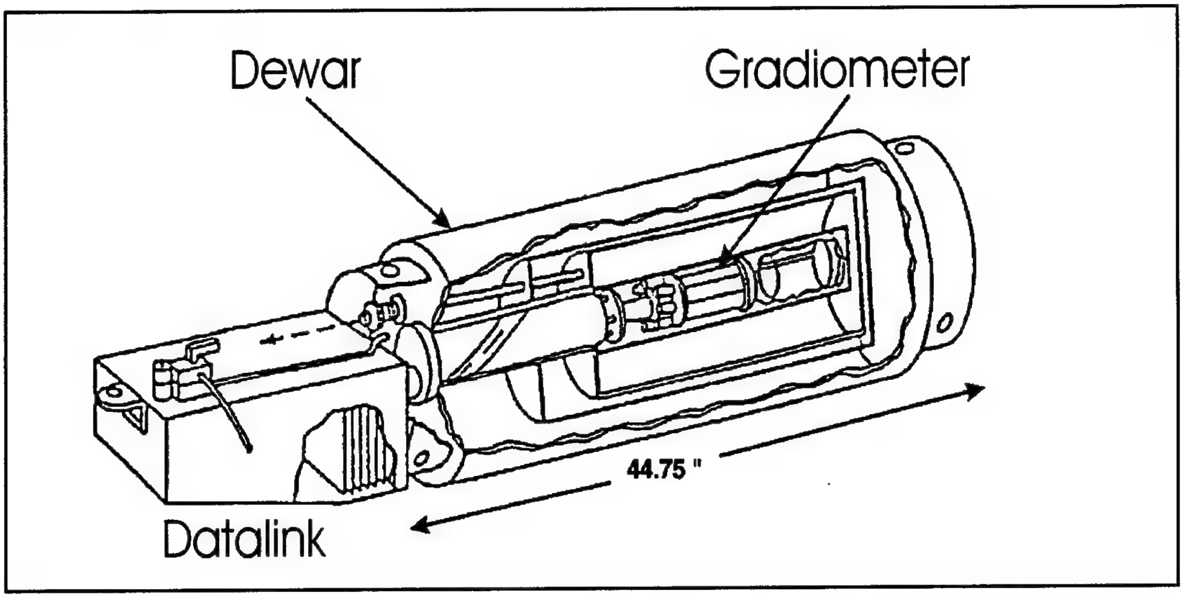

FIGURE C-2. MAGNETIC SENSOR - SGMS

The gradiometer data, which is collected at a 20 Hz rate from each of the superconducting channels and the magnetometer channels, is passed to the GEM computer system. GEM performs the localization algorithm calculation and formats the data for transfer to the topside instrumentation shack where it is recorded and distributed for further processing and display.

The entire SGMS (dewar and datalink) is mounted in a 9-ft (2.7 m) long, 21-in (53 cm) diameter fiberglass tow body section with fiberglass nose and tail sections attached at the ends. (Fiberglass is used because metal would produce extraneous signals in the gradiometer from eddy currents induced by vehicle motion.) The helium outgassed from the dewar passes through a small hose in the gradiometer vehicle pigtail to a pump in the tail of the active tow body, where it is pumped into the water. This disposal of the helium gas is necessary to prevent helium from building up in the gradiometer section and eventually penetrating into the dewar vacuum spaces in sufficient quantities to cause the dewar to lose its hold time.

APPPENDIX D

PHASE II CONTROL AND PROCESSING

APPENDIX D: PHASE II MUDSS CONTROL AND PROCESSING

Phase II testing of Mobile Underwater Debris Survey System (MUDSS) included on-site processing and control capabilities developed since Phase I. The functions of these on-site systems are described in the following sections.

GEM

GEM is a 10 billion floating point operations per second (gigaflops) embedded real-time processing system housed within a 5-ft (1.6 m) long, 21-in (53 cm) diameter section of the active tow body. GEM uses 110-V AC power supplied by the tow body. The approximate power load is 1400 W. There are two power controls for the shell section, one for cooling fans and one for electronics. They are interlocked, forcing the cooling fans to be powered up before the electronics can receive power.

GEM receives raw sonar data from the synthetic aperture sonar (SAS) array elements, all the raw gradiometer data, motion data from the Doppler section, global positioning system (GPS) data (for position information) from the GPS float, and GEM control data from topside. The SAS data are preprocessed, motion compensated, beamformed, analyzed for targets, formatted, and sent topside by GEM. The gradiometer data are also preprocessed, motion compensated, analyzed for targets, formatted, and sent topside by GEM. No long-term data recording takes place in GEM.

Primary tasks preformed by GEM are:

- SAS sensor data processing, beamforming and image processing
- Automated Target Detection (ATR) for SAS images
- Electro-optic identification (EOID) sensor data storage
- Magnetics data processing, target localization

Communications between the active tow body and the surface control and display computers are not handled by GEM.

ELIOT

Topside command and control for the sensors and active tow body are done with Eliot, a custom designed PC computer with a pair of high resolution (1600 x 1200 pixel) touch screen monitors which displays and records data for the operators aboard the towing platform. See Figure D-1.

FIGURE D-3. SENSOR DISPLAY AND CONTROL

During the acoustic and magnetic survey Eliot controls the MUDSS system, and also displays and records the sensor data. The heart of the Eliot system, high resolution (1600 x 1200 pixel) touch screen monitors, are used to display all SAS waterfall images. The acoustically and magnetically unexploded ordnance (UXO)-like targets found by the automated sonar and magnetics data analysis routines running on GEM are high-lighted on the waterfall images. The waterfall images are displayed at 3-in x 3-in (7.5 cm x 7.5 cm) resolution; a zoom feature allows the observer to enlarge the area around a target for closer inspection. Either of the two observers stationed at the high resolution monitors can add to the observers' list of positions of acoustically and magnetically UXO-like targets by simply touching or clicking on a target on the screen. The targets on the observers' list, which are automatically geocoded, are the ones that are later reacquired for identification. The observers' target list is saved in an ASCII file on Eliot and copied to 3.5-in (8.9 cm) disks.

With one exception, Eliot records the full high-speed data stream on 35-Gigabyte tape cartridges during the acoustic and magnetic survey. This exception is SeaBat model sonar video data, which is recorded separately on a video cassette, including SAS images, at their full resolution of 3-in x 3-in (7.5 cm x 7.5 cm) for the low frequency (LF) SAS and 1-in x 1-in (0.64 cm x 0.64 cm) for the high frequency (HF) SAS. Eliot data is recorded at the high-speed data transmission rate of approximately seven Mbits/second. While each cartridge is capable of holding in excess of nine hours of data, in practice only three hours of data or less are recorded on one cartridge. This guards against losing too much data in the event of a tape failure.

After each cartridge is dismounted, it is taken to the replay computer in the auxiliary van, where it is copied and archived. An observer then replays the tape copy, reviewing the waterfall images on the replay computer's high-resolution monitor. During this review, it is possible to pause the image, scroll backward or forward through images covering approximately 700-ft (213 m) on the bottom, and zoom in on acoustic targets. The reviewer can make a separate target list for comparison with the initial observers' target list.

If Eliot detects the loss of any data in the high data rate signal, it invokes a fault indicator, and display updates are substituted with a predefined pattern to indicate data loss to the operator.

During the EOID reacquisition phase of the survey, the EOID images are written to a revolving 128-Mbyte buffer in GEM. As the EOID images waterfall down a high-resolution monitor in the MilVan, the observer may request to record a 1-Mbyte snapshot around a target seen on the monitor. A 1-Mbyte image centered on the target is then sent up to the MilVan by the high-speed link and recorded on 1-GByte Jaz cartridges. It is also possible to send the entire 128-Mbyte buffer to the MilVan for recording.

For backup, the EOID images are written to 1.3-GByte magneto-optic disks and 650-MByte CD-ROM disks. The images may also be output to a laser printer.

TOW VEHICLES AND CABLES

The MUDSS sensors and GEM processor are contained in the two tow bodies connected one after the other with a tow cable. The tow cable from the support ship to the active tow body provides power for both tow bodies and communication between the control and display computers on the ship and the sensors and computers aboard the two tow bodies.

ACTIVE TOW BODY

The MUDSS active tow body consists of 21-in (53 cm) tubular sections joined by MK 48 bands. In order from forward to aft, these sections are: the nose section (housing the SeaBat), the active wing section, the GEM section, the SAS section, the motion measuring package section (which includes a Doppler sonar), the EOID section, a small section housing the helium pump, and the active tail section. The total length of the active tow body is approximately 28 ft (8.5 m). The tow body is slightly positively buoyant and has a total weight of approximately 3600 lbs (1633 kg).

The specially designed sections for the active wing and tail system control the towbody motion. The wing section includes the structure for supporting a variable incidence 3-ft (0.9 m)
wing with mechanical and electrical connections to the tow cable. The tail section supports three fully deflectable fins arranged in an inverted 'Y' formation. Communications from the active tow body to the towing vessel, *PSC-8*, are carried through a cable connected at the wing section.

The active towbody receives 1200-V AC, 400-Hz power through the tow cable. A transformer in the nose converts the power to 120-V AC and 220-V AC for distribution to the various electronic subassembly DC power supplies. This serves to help isolate noise and to distribute the total power conversion heat throughout the active tow body.

The power up sequence for the wing and tail is carefully designed to avoid dangerous initial settings. Power up occurs when power from the tow cable transformer is applied to the wing and tail processors, which starts a 30-sec "BOOT" sequence. The wing processor then requests a data set from the tail processor that initiates an A/D conversion of all tail analog input channels. When the wing processor has successfully received the expected data set from the tail processor, it addresses a group of wing digital to analog (D/A) channels that sets the wing position to neutral, and energizes a solid state relay controlling the power input to the tail actuator power supply. Meanwhile, the tail processor is executing a similar routine to command the tail fins to move to the neutral position prior to energizing the fin actuators.

Temporary disruption of tow body power initiates a "BOOT" sequence by the wing and tail processors. This sequence activates a tail "deadman circuit", which after one second commands the tail fins to the neutral position. When the "BOOT" sequence is complete and processor activity pulses are detected by the "deadman circuit" for a quarter of a second, fin control is transferred back to the tail processor.

If communication is lost for more than one second between the wing and the tail processors, the deadman circuit initiates a "BOOT" sequence in the tail processor while commanding the tail fins to a neutral position. The tail fins then remain in the neutral position until the "BOOT" sequence is complete and processor communication is reestablished. Tail fin control is then passed back to the tail processor.

MAGNETICS TOWED VEHICLE

SGMS is mounted in a 9-ft (2.7 m) long tow body section in the magnetics towed vehicle, which is slightly positively buoyant and passive. The SGMS section is a 21-in (53 cm) fiberglass tube joined by MK 48 bands to forward nose and aft tail fiberglass sections making up the whole towed vehicle. The tow cable from the active tow body is attached at the head of the nose of the towed vehicle. The magnetics towed vehicle is approximately 14-ft (4.3 m) long and weighs approximately 1500 lbs(680 kg).

TOW CABLES

The tow cable from the *PSC-8* to the active tow body is 0.425-in (0.1 cm) diameter and has two layers of armor steel outer layers over a polyurethane inner jacket. The inner jacket contains two fiber optic cables for high data-rate transmission, two single conductors for power transmission to the tow body (1200-V AC voltage rating, 4-Amps current rating), and two twisted pair, copper braid conductors for low data-rate transmission. To reduce drag and suppress cable strumming during towing, plastic ribbon fairing with ribbons 0.25-in (0.64 cm) wide and 3-in (7.5 cm) long is attached to the cable armor on the last one hundred feet of cable nearest the tow body.

The cable from the active tow body to the magnetics towed vehicle contains six shielded, twisted wire pairs and a helium vent line that runs from the gradiometer to the helium pump in the rear of the active tow body. Helium boiled off from the dewar is pumped out to the surrounding sea by the helium pump in the active tow body. The cable between the two towbodies is 75-ft (23 m) long.

In the event of failure of the helium pump, pressure will slowly build in the gradiometer pressure vessel. Two check valves on the front plate of the pressure vessel allow the helium to vent directly to the water when the overpressure exceeds one psi.

TOW PLATFORM AND SUPPORT SYSTEMS FOR MUDSS OPEN WATER CONFIGURATION

Any craft of opportunity may be used so long as it fulfils the following requirements:

- Sufficient deck space for the control van, 9-ft (2.7 m) by 20-ft (6.1 m).
- Ability to support rigging and both tow bodies at eight knots.
- Ability to support a crane for emergency recovery of the tow bodies.
- Sufficient power supply to operate the tow body sensors and computers, control van computers on deck and other support computer in boat cabin.
- SeaBat display for boat driver.
- GPS navigation for search.

The craft of opportunity used for the MUDSS search was CSS boat, *PSC8*, Figure D-2.

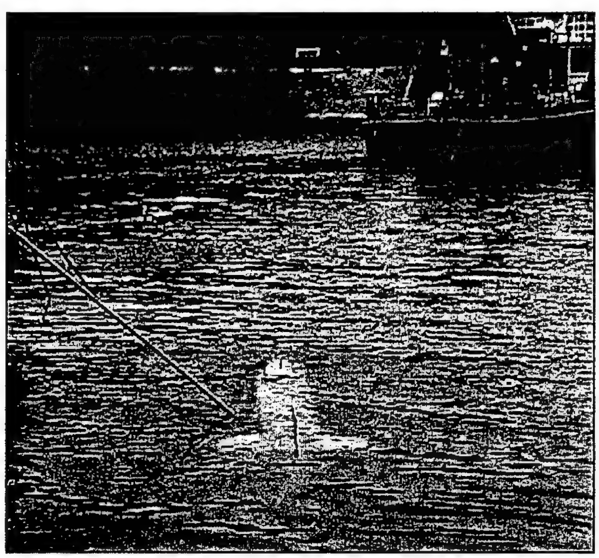

FIGURE D-4. PSC-8 WITH ACTIVE TOW BODY AND TOW VEHICLE

APPPENDIX E

PHASE II, CHOCTAWHATCHEE BAY DATA

SONAR DATA

Table E-1 lists the acoustic targets that the CSS sonar operator selected as potential UXO targets during the June 1999 review of the Choctawhatchee Bay data. The operator analyzed all ten acoustic data tapes from the Technical Demonstration Test. The operator target selection criteria was subjective but was based on identifying acoustic images that exhibit some/all of four key target features: (1) Reflected highlight; (2) Shadow; (3) Highlight/Shadow Size and (4) Highlight/Shadow Shape. The data list the date, time and coordinates (Latitude/Longitude) for each operator-selected target as well as an acoustic confidence number between one and five. The acoustic confidence number measures the operator's best judgment whether the detected image is the image of a potential UXO target where five is strongest and one is weakest. The data also include a column for additional operator comments on each target.

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
1	19-Nov-98	19:25:58	Jun23,1999	30.46990	86.46717	3	-
1	19-Nov-98	19:27:00	Jun23,1999	30.46959	86.46513	3	-
1	19-Nov-98	19:34:28	Jun23,1999	30.46951	86.45080	1	Possible boat
1	19-Nov-98	19:45:50	Jun23,1999	30.46791	86.45628	3	shadow, no magnetics
1	19-Nov-98	19:59:24	Jun23,1999	30.46892	86.46632	3	high and low, no mag
1	19-Nov-98	20:05:12	Jun23,1999	30.46906	86.45518	3	high and low, no mag
1	19-Nov-98	20:06:36	Jun23,1999	30.46931	86.45246	2	high, shadow
1	19-Nov-98	20:21:53	Jun23,1999	30.46729	86.46145	2	high and low
1	19-Nov-98	20:34:37	Jun23,1999	30.46877	86.46292	2	-
1	19-Nov-98	20:35:39	Jun23,1999	30.46862	86.46093	2	displaced shadow
1	19-Nov-98	20:38:48	Jun23,1999	30.46868	86.45486	1	large buried object
1	19-Nov-98	20:39:07	Jun23,1999	30.46846	86.45425	3	high and low
1	19-Nov-98	20:43:17	Jun23,1999	30.46842	86.44621	2	displaced shadow
1	19-Nov-98	20:56:38	Jun23,1999	30.46665	86.46304	1	high and low
1	19-Nov-98	21:17:23	Jun23,1999	30.46489	86.44531	2	high and low
1	19-Nov-98	21:23:04	Jun23,1999	30.46628	86.44817	2	high and low
1	19-Nov-98	21:25:19	Jun23,1999	30.46633	86.45255	2	high with shadow
1	19-Nov-98	21:56:50	Jun23,1999	30.46433	86.45720	3	-
1	19-Nov-98	21:57:02	Jun23,1999	30.46431	86.45681	3	-
1	19-Nov-98	22:19:06	Jun23,1999	30.46712	86.44605	2	high and low
1	19-Nov-98	22:20:13	Jun23,1999	30.46663	86.44407	2	high with shadow

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS, CONTINUED

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
1	19-Nov-98	22:23:24	Jun23,1999	30.46548	86.44559	3	high and low
2	20-Nov-98	15:46:50	Jun23,1999	30.46224	86.44182	3	-
2	20-Nov-98	16:03:49	Jun23,1999	30.46215	86.47395	3	-
2	20-Nov-98	16:21:03	Jun23,1999	30.46297	86.44227	3	-
2	20-Nov-98	16:50:25	Jun23,1999	30.46292	86.47343	3	-
2	20-Nov-98	16:56:17	Jun23,1999	30.46263	86.46234	2	-
2	20-Nov-98	17:17:03	Jun23,1999	30.46067	86.45921	1	-
2	20-Nov-98	17:30:11	Jun23,1999	30.46198	86.46512	3	-
2	20-Nov-98	17:35:48	Jun23,1999	30.46204	86.45420	1	-
2	20-Nov-98	18:00:54	Jun23,1999	30.45944	86.47385	3	boat hull?
2	20-Nov-98	18:01:02	Jun23,1999	30.45921	86.47382	3	debris from boat
2	20-Nov-98	18:01:03	Jun23,1999	30.45931	86.47412	1	man-made, large debris
2	20-Nov-98	18:37:28	Jun23,1999	30.45916	86.47350	3	-
2	20-Nov-98	18:41:34	Jun23,1999	30.45718	86.46839	3	-
2	20-Nov-98	18:57:30	Jun23,1999	30.45886	86.44269	2	-
2	20-Nov-98	19:07:46	Jun23,1999	30.45867	86.46144	1	-
2	20-Nov-98	19:17:32	Jun23,1999	30.45653	86.47053	3	good shadow
2	20-Nov-98	19:19:43	Jun23,1999	30.45665	86.46627	1	-
3	20-Nov-98	19:51:07	Jun23,1999	30.45822	86.45989	3	high and low
3	20-Nov-98	21:08:38	Jun23,1999	30.45317	86.47215	3	-
3	20-Nov-98	21:15:14	Jun23,1999	30.45442	86.46486	2	-
3	20-Nov-98	19:37:28	Jun23,1999	30.45822	86.44364	3	high, low, and mag
4	21-Nov-98	14:45:24	Jun24,1999	30.48136	86.47447	3	-
4	21-Nov-98	15:05:08	Jun24,1999	30.46563	86.46239	3	-
4	21-Nov-98	15:06:52	Jun24,1999	30.46313	86.46423	3	-
4	21-Nov-98	15:11:12	Jun24,1999	30.46000	86.47222	4	-
4	21-Nov-98	15:11:59	Jun24,1999	30.45922	86.47355	1	-
4	21-Nov-98	15:12:26	Jun24,1999	30.45883	86.47436	4	-
4	21-Nov-98	15:13:18	Jun24,1999	30.45743	86.47521	3	-
4	21-Nov-98	15:35:00	Jun24,1999	30.44968	86.44231	3	-
4	21-Nov-98	15:34:57	Jun24,1999	30.44968	86.44239	3	-
4	21-Nov-98	15:37:51	Jun24,1999	30.45104	86.44571	3	-
4	21-Nov-98	16:01:25	Jun24,1999	30.44872	86.45872	3	-
4	21-Nov-98	16:07:23	Jun24,1999	30.44897	86.44699	3	-
4	21-Nov-98	16:14:14	Jun24,1999	30.45088	86.44844	1	-
4	21-Nov-98	16:23:34	Jun24,1999	30.45049	86.46731	3	-

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS, CONTINUED

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
4	21-Nov-98	16:40:40	Jun24,1999	30.44833	86.44939	3	-
4	21-Nov-98	17:06:53	Jun24,1999	30.44976	86.44904	3	-
4	21-Nov-98	17:10:20	Jun24,1999	30.45014	86.45560	3	-
4	21-Nov-98	17:20:35	Jun24,1999	30.45039	86.47491	3	-
4	21-Nov-98	17:20:39	Jun24,1999	30.45039	86.47503	3	-
4	21-Nov-98	17:38:05	Jun24,1999	30.44798	86.44572	3	-
4	21-Nov-98	17:57:27	Jun24,1999	30.44528	86.47209	3	-
4	21-Nov-98	18:19:17	Jun24,1999	30.44488	86.44728	3	-
4	21-Nov-98	18:27:20	Jun24,1999	30.44489	86.46432	3	-
5	21-Nov-98	18:38:26	Jun23,1999	30.44556	86.47411	3	-
5	21-Nov-98	18:40:46	Jun23,1999	30.44827	86.47503	3	strong magnetics
5	21-Nov-98	18:49:53	Jun23,1999	30.44658	86.46210	1	-
5	21-Nov-98	19:15:56	Jun23,1999	30.44424	86.46903	3	-
5	21-Nov-98	19:33:48	Jun23,1999	30.44610	86.45142	3	high,low, and mag
5	21-Nov-98	19:34:11	Jun23,1999	30.44608	86.45068	3	high,low, and mag
5	21-Nov-98	20:36:02	Jun23,1999	30.46692	86.46150	3	high and low
5	21-Nov-98	20:36:17	Jun23,1999	30.46714	86.46199	1	pipe or log
5	21-Nov-98	20:46:22	Jun23,1999	30.46869	86.46822	3	-
5	21-Nov-98	20:57:57	Jun23,1999	30.46857	86.44634	3	-
5	21-Nov-98	20:59:29	Jun23,1999	30.46856	86.44337	1	-
5	21-Nov-98	21:14:26	Jun23,1999	30.46663	86.46785	3	high and low, and mag
5	21-Nov-98	21:23:07	Jun23,1999	30.46821	86.46407	4	high,low, and mag
5	21-Nov-98	21:52:30	Jun23,1999	30.46765	86.47306	4	high,low,and mag
5	21-Nov-98	22:19:25	Jun23,1999	30.46554	86.46186	2	high and magnetic
6	22-Nov-98	17:02:19	Jun25,1999	30.46170	86.46712	3	-
6	22-Nov-98	17:10:42	Jun25,1999	30.46243	86.45229	5	-
6	22-Nov-98	17:10:47	Jun25,1999	30.46243	86.45209	5	-
6	22-Nov-98	17:10:44	Jun25,1999	30.46248	86.45219	3	-
6	22-Nov-98	17:19:44	Jun25,1999	30.46249	86.45187	5	-
6	22-Nov-98	17:19:48	Jun25,1999	30.46244	86.45201	5	-
6	22-Nov-98	17:19:53	Jun25,1999	30.46243	86.45216	5	-
6	22-Nov-98	17:56:02	Jun25,1999	30.45910	86.44879	4	-
6	22-Nov-98	18:11:28	Jun25,1999	30.46073	86.47384	3	-
6	22-Nov-98	18:11:31	Jun25,1999	30.46072	86.47372	3	-

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS, CONTINUED

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
6	22-Nov-98	19:22:29	Jun25,1999	30.45907	86.47418	4	-
6	22-Nov-98	19:31:16	Jun25,1999	30.45972	86.45666	2	-
6	22-Nov-98	19:33:18	Jun25,1999	30.45951	86.45256	3	-
6	22-Nov-98	19:39:19	Jun25,1999	30.45865	86.44072	3	-
7	22-Nov-98	21:01:10	Jun25,1999	30.45622	86.44379	3	-
7	22-Nov-98	21:01:48	Jun25,1999	30.45590	86.44511	3	-
7	22-Nov-98	21:33:39	Jun25,1999	30.45370	86.44657	2	-
7	22-Nov-98	21:54:32	Jun25,1999	30.45535	86.47427	3	-
7	22-Nov-98	22:56:43	Jun25,1999	30.46356	86.44382	3	-
7	22-Nov-98	23:20:39	Jun25,1999	30.46264	86.46233	1	-
7	22-Nov-98	23:25:36	Jun25,1999	30.46243	86.45227	5	-
7	22-Nov-98	23:25:41	Jun25,1999	30.46244	86.45211	5	-
7	22-Nov-98	23:47:31	Jun25,1999	30.46416	86.46835	1	-
7	22-Nov-98	23:57:42	Jun25,1999	30.46261	86.46231	2	-
7	22-Nov-98	0:02:45	Jun25,1999	30.46243	86.45226	5	-
7	22-Nov-98	0:02:50	Jun25,1999	30.46244	86.45211	5	-
7	22-Nov-98	0:02:46	Jun25,1999	30.46234	86.45224	3	-
7	22-Nov-98	0:16:38	Jun25,1999	30.46430	86.45712	3	-
8	23-Nov-98	20:34:27	Jun24,1999	30.46462	86.45176	3	-
8	23-Nov-98	20:37:16	Jun24,1999	30.46458	86.44620	3	-
8	23-Nov-98	20:46:31	Jun24,1999	30.46204	86.45409	1	-
8	23-Nov-98	20:55:40	Jun24,1999	30.46194	86.47158	3	-
8	23-Nov-98	20:56:43	Jun24,1999	30.46203	86.47335	3	-
8	23-Nov-98	21:48:43	Jun24,1999	30.44953	86.47120	3	-
8	23-Nov-98	21:48:47	Jun24,1999	30.44955	86.47131	3	-
8	23-Nov-98	22:18:19	Jun24,1999	30.44944	86.45892	3	-
8	23-Nov-98	22:50:53	Jun24,1999	30.44873	86.45259	3	-
8	23-Nov-98	23:35:01	Jun24,1999	30.44821	86.46668	3	-
8	23-Nov-98	23:41:50	Jun24,1999	30.44520	86.47289	3	-
9	24-Nov-98	16:27:31	Jun24,1999	30.46265	86.46234	2	high,low, and mag
9	24-Nov-98	16:29:28	Jun24,1999	30.46275	86.45876	3	HLM and good shadow
9	24-Nov-98	16:32:58	Jun24,1999	30.46243	86.45225	5	HLM and good shadow
9	24-Nov-98	16:33:03	Jun24,1999	30.46244	86.45210	1	HLM and good shadow
9	24-Nov-98	16:33:01	Jun24,1999	30.46240	86.45216	5	good shadow with highlights

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS, CONTINUED

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
9	24-Nov-98	16:33:05	Jun24,1999	30.46244	86.45203	5	target
9	24-Nov-98	16:33:04	Jun24,1999	30.46244	86.45206	5	-
9	24-Nov-98	16:37:45	Jun24,1999	30.46465	86.44473	2	-
9	24-Nov-98	16:42:27	Jun24,1999	30.46239	86.45180	5	-
9	24-Nov-98	16:42:31	Jun24,1999	30.46243	86.45200	5	-
9	24-Nov-98	16:42:38	Jun24,1999	30.46243	86.45216	5	-
9	24-Nov-98	16:42:34	Jun24,1999	30.46246	86.45203	4	-
9	24-Nov-98	16:43:38	Jun24,1999	30.46205	86.45407	1	pipe or log
9	24-Nov-98	16:46:40	Jun24,1999	30.46064	86.45918	1	-
9	24-Nov-98	16:50:39	Jun24,1999	30.46205	86.45416	1	-
9	24-Nov-98	16:51:42	Jun24,1999	30.46243	86.45223	4	-
9	24-Nov-98	16:51:47	Jun24,1999	30.46245	86.45209	4	-
9	24-Nov-98	16:55:22	Jun24,1999	30.45997	86.44623	3	-
9	24-Nov-98	16:55:36	Jun24,1999	30.46019	86.44581	3	log
9	24-Nov-98	16:56:25	Jun24,1999	30.46049	86.44437	1	-
9	24-Nov-98	16:57:11	Jun24,1999	30.46180	86.44412	3	-
9	24-Nov-98	17:01:23	Jun24,1999	30.46244	86.45201	5	-
9	24-Nov-98	17:01:28	Jun24,1999	30.46242	86.45217	5	-
9	24-Nov-98	17:01:21	Jun24,1999	30.46243	86.45194	5	-
9	24-Nov-98	17:01:25	Jun24,1999	30.46238	86.45208	5	-
9	24-Nov-98	17:06:03	Jun24,1999	30.46179	86.46102	4	-
9	24-Nov-98	17:09:12	Jun24,1999	30.45950	86.46655	3	-
9	24-Nov-98	17:40:08	Jun24,1999	30.44471	86.44566	3	-
9	24-Nov-98	17:43:37	Jun24,1999	30.44441	86.45264	1	-
9	24-Nov-98	18:00:39	Jun24,1999	30.44699	86.46778	3	-
9	24-Nov-98	18:02:29	Jun24,1999	30.44671	86.46420	4	-
9	24-Nov-98	18:02:55	Jun24,1999	30.44691	86.46336	3	-
9	24-Nov-98	18:03:33	Jun24,1999	30.44661	86.46212	1	-
9	24-Nov-98	18:25:26	Jun24,1999	30.44407	86.46082	3	-
9	24-Nov-98	18:31:34	Jun24,1999	30.44398	86.47269	3	-
9	24-Nov-98	18:46:38	Jun24,1999	30.44607	86.44946	1	-
9	24-Nov-98	18:50:08	Jun24,1999	30.44624	86.44257	4	-
9	24-Nov-98	19:26:34	Jun24,1999	30.44586	86.44688	1	-
10	24-Nov-98	19:40:35	Jun24,1999	30.44911	86.46465	3	-

TABLE E-1. OPERATOR SELECTED ACOUSTIC TARGETS, CONTINUED

Tape#	Zulu Test	Test Time	Review Date	N Latitude	W Longitude	Confidence	Comment
10	24-Nov-98	19:51:18	Jun24,1999	30.46096	86.47381	3	-
10	24-Nov-98	20:08:19	Jun24,1999	30.46204	86.45415	1	-
10	24-Nov-98	20:09:18	Jun24,1999	30.46243	86.45225	5	-
10	24-Nov-98	20:09:23	Jun24,1999	30.46243	86.45209	5	-
10	24-Nov-98	20:18:35	Jun24,1999	30.46244	86.45201	5	-
10	24-Nov-98	20:18:40	Jun24,1999	30.46242	86.45218	5	-
10	24-Nov-98	20:21:32	Jun24,1999	30.46142	86.45737	4	-
10	24-Nov-98	20:22:45	Jun24,1999	30.46066	86.45923	1	-
10	24-Nov-98	20:28:20	Jun24,1999	30.46264	86.45271	3	-
10	24-Nov-98	20:28:35	Jun24,1999	30.46243	86.45225	5	-
10	24-Nov-98	20:28:40	Jun24,1999	30.46244	86.45210	5	-
10	24-Nov-98	20:28:45	Jun24,1999	30.46240	86.45194	2	-
10	24-Nov-98	20:28:38	Jun24,1999	30.46241	86.45216	5	-
10	24-Nov-98	20:34:44	Jun24,1999	30.46081	86.44333	3	-

MAGNETIC TARGETS

Table E-2 lists the sensor target results from the Choctawhatchee Bay tests after processing the magnetic data, using the Vaizer-Lathrop algorithm to calculate the target position and magnetic moment vector. Table E-2 lists only Choctawhatchee Bay magnetic targets with dipole fit confidence values, $\alpha > 0.4$. The α is a threshold criteria established to calculate the fit of the data to that of a magnetic dipole moment. Previous analysis has shown that requiring a fit greater than 0.4 is a reasonable criteria for real targets. The data for each magnetic target include the test date, time, calculated magnetic moment magnitude, cosine θ where θ is the angle between the earth's magnetic field direction and the target's magnetic moment, dipole fit α, y and z target coordinates with respect to the sensor in feet, and target latitude and target longitude. The targets in Table E-2 are listed in order of decreasing value of dipole fit.

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4

Date	Time Zulu	Magn Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
24-Nov	16:26:56	31207.4707	-0.65719	14.15526	6.362972	-15.902409	-19.4823	4.6828	30.46257	-86.46343
21-Nov	20:37:20	37015.73828	0.291541	11.759234	-8.596257	-12.95016	19.28843	7.92793	30.46711	-86.46400
21-Nov	21:48:37	26755.19336	-0.421311	10.975259	-1.028917	-13.704809	18.92011	2.02189	30.46597	-86.46798
22-Nov	18:55:48	16222.14941	-0.469459	10.503093	-2.219067	-10.964843	-19.0358	-1.88713	30.46011	-86.45873
24-Nov	16:41:05	15529.49902	-0.517231	9.336432	8.429298	-9.383825	18.53281	-9.41213	30.46234	-86.44920
22-Nov	21:16:30	9673.141602	-0.669624	7.588383	-2.551413	-11.10958	19.16261	0.551395	30.45619	-86.47266
21-Nov	21:47:41	93966.3125	-0.872879	7.56544	7.539513	-17.389521	19	-7.53951	30.46586	-86.46615
22-Nov	17:07:29	24584.14648	-0.268215	7.308131	-4.57179	-11.027304	-18.9173	-4.90269	30.46236	-86.45844
22-Nov	17:56:03	10346.44141	-0.883047	7.121546	3.073705	-9.662384	19.16813	-1.74084	30.45902	-86.44882
21-Nov	18:49:12	173886.9531	0.687035	6.998588	22.129761	-17.694099	-19.3833	21.79479	30.44665	-86.46341
22-Nov	20:25:27	16513.63867	0.2838	6.472543	-10.593627	-11.703802	18.81222	10.92361	30.45677	-86.45870
22-Nov	18:45:21	10969.84961	-0.716128	6.28671	-6.798039	-10.318835	19	6.798039	30.45850	-86.47245
21-Nov	21:13:45	66374.83594	-0.952652	6.123984	-6.487507	-16.841887	18.63443	7.472999	30.46660	-86.46651
22-Nov	22:46:23	6971.877441	-0.973763	5.845627	-3.465608	-12.720322	-18.7926	-4.45524	30.45263	-86.44882
22-Nov	20:23:53	12860.97461	-0.556093	5.81883	-2.960818	-11.703973	18.94543	3.291963	30.45684	-86.45578
23-Nov	0:14:29	186322.5938	-0.660483	5.464855	21.153179	-6.397834	15.87114	-23.5916	30.46275	-86.45370
22-Nov	22:01:24	13153.36231	-0.599151	5.372072	-1.269283	-12.164659	-18.9441	-1.9316	30.45316	-86.46270
22-Nov	17:18:18	16589.85352	-0.54371	5.254983	-4.86033	-10.247757	19.15805	4.194279	30.46234	-86.44921
22-Nov	17:42:10	25829.62109	0.207	4.874785	-15.975845	-9.781433	-17.8393	-17.2623	30.46123	-86.45890
22-Nov	18:45:02	20385.96875	-0.586113	4.610852	-10.18846	-11.285686	19.344	9.519163	30.45851	-86.47188

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	18:55:39	6480.330078	-0.551039	4.510168	4.128785	-11.495641	-18.8443	4.78936	30.46015	-86.45902
21-Nov	21:22:35	146458.1094	-0.29086	4.36998	16.863359	-12.527681	-20.13	15.49691	30.46825	-86.46507
22-Nov	23:18:11	56778.51953	0.201976	4.343009	-15.423434	-12.870183	-17.8778	-16.7112	30.46260	-86.46738
22-Nov	21:10:58	7517.355469	-0.662934	4.266134	-5.233372	-14.873817	18.22059	7.509881	30.45624	-86.46260
21-Nov	20:12:36	62711.87891	-0.9938	4.195496	-8.950202	-19.760464	-18.1476	-10.5721	30.46933	-86.46675
21-Nov	22:11:02	33948.30078	0.326022	4.137178	-6.321825	-17.297707	19	6.321825	30.46542	-86.44543
24-Nov	19:50:04	986436.125	0.359093	4.036725	-36.173332	-12.18117	33.17701	-23.8494	30.45916	-86.47440
22-Nov	20:32:48	6937.510742	-0.427658	4.035944	0.042991	-10.387218	18.65912	3.58317	30.45663	-86.47253
21-Nov	19:26:03	262821.3438	-0.592616	3.930894	30.611124	-16.059217	-19	30.61112	30.44602	-86.46600
21-Nov	22:18:42	20609.32617	-0.494028	3.833697	-9.39231	-9.608771	19.16102	9.059284	30.46539	-86.46042
22-Nov	21:57:07	39771.13281	-0.73362	3.788634	-3.695401	-16.178194	-19.2498	-2.02538	30.45323	-86.47078
21-Nov	21:28:07	23605.24609	-0.610791	3.758584	9.02074	-12.859466	-19.3032	8.352154	30.46829	-86.45452
23-Nov	0:00:03	7791.450684	-0.461923	3.754245	-1.853017	-9.776534	-18.9648	-2.18433	30.46257	-86.45766
22-Nov	20:30:47	3011.476074	-0.918727	3.732454	0.849152	-11.594376	19.01295	0.478289	30.45681	-86.46862
22-Nov	18:07:06	827251.75	-0.37787	3.718966	28.197208	-9.318335	16.98678	-29.4539	30.45903	-86.46859
21-Nov	21:23:04	124756.4297	0.267365	3.716909	5.03269	-13.947733	-19.0849	4.700328	30.46830	-86.46416
22-Nov	18:09:30	199277.6719	0.263301	3.702323	-20.232304	-8.37683	20.69106	18.49935	30.45917	-86.47312
22-Nov	20:32:14	19932.80078	-0.216092	3.648846	-9.553318	-11.756193	18.09507	11.17292	30.45673	-86.47144
21-Nov	15:27:34	32114.19922	-0.91105	3.614915	-1.034928	-17.530846	-18.9198	-2.02789	30.44954	-86.45711
22-Nov	22:03:14	40705.8125	-0.546997	3.575266	-13.102695	-16.227013	-19	-13.1027	30.45316	-86.45931
22-Nov	21:25:41	26815.94727	-0.528114	3.466559	-12.312263	-12.502294	-18.5587	-12.9679	30.45371	-86.46197
24-Nov	20:17:06	15209.47656	-0.488831	3.446592	11.569971	-9.243472	19.57949	-10.5597	30.46233	-86.44920
21-Nov	21:01:56	18935.36719	-0.667481	3.421598	12.180752	-10.116215	18.33647	-13.1584	30.46633	-86.44354
21-Nov	18:56:42	17107.93945	-0.754115	3.406495	-11.24064	-19.930584	-18.3857	-12.2196	30.44662	-86.44904
22-Nov	23:45:48	18326.83789	-0.871549	3.38267	4.157583	-16.051783	19	-4.15758	30.46414	-86.46492
22-Nov	17:11:24	41922.76172	-0.20473	3.323554	-11.410423	-11.741365	-19.9222	-9.71104	30.46224	-86.45095
22-Nov	19:19:25	13379.65039	-0.625403	3.322944	2.851358	-9.96737	18.82473	-3.84183	30.45794	-86.46960
21-Nov	18:52:02	11903.10254	0.081961	3.228261	-11.174788	-17.10145	-18.8021	-11.5047	30.44656	-86.45799
22-Nov	21:55:58	47472.86719	0.377136	3.176042	-8.744171	-12.726071	-20.8717	-1.3544	30.45354	-86.47310
22-Nov	17:34:23	19155.78906	0.169982	3.077853	-9.256021	-11.61294	-19.7274	7.583129	30.46207	-86.47345
22-Nov	21:59:21	25890.3457	-0.272397	3.005488	-17.321596	-12.310684	-18.3839	-17.9741	30.45318	-86.46655
24-Nov	19:49:07	28669.06836	-0.840736	2.97859	-15.180535	-10.054584	14.84663	-19.262	30.45757	-86.47449
24-Nov	20:06:11	22969.62695	-0.230872	2.957125	17.190737	-10.356402	-19.8737	16.17279	30.46236	-86.45842
22-Nov	22:49:09	3292.497314	0.188033	2.955898	11.258142	-11.636353	-18.8006	11.58802	30.45256	-86.44343
21-Nov	20:29:27	16579.50977	-0.254019	2.943145	12.28353	-14.157838	19	-12.2835	30.46705	-86.44900

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	21:17:14	28870.35352	-0.416088	2.911776	15.828013	-11.597805	13.54213	-20.6915	30.45652	-86.47396
22-Nov	22:44:05	5403.138672	-0.606982	2.89342	-0.749874	-11.919684	-18.767	-3.0598	30.45265	-86.45331
24-Nov	16:29:33	28339.0293	-0.292817	2.882034	-15.844596	-13.289184	-19	-15.8446	30.46247	-86.45857
24-Nov	16:29:33	28339.0293	-0.292817	2.882034	-15.844596	-13.289184	-19	-15.8446	30.46247	-86.45857
21-Nov	16:05:04	15311.25098	-0.394283	2.806095	2.495733	-13.732089	-19.1452	0.830277	30.44894	-86.45157
22-Nov	23:22:40	7751.193848	0.282301	2.786487	8.327099	-9.255951	-19.279	7.658936	30.46254	-86.45823
21-Nov	19:25:59	264896.5938	-0.105887	2.785517	-36.113632	-17.310316	-21.4729	-34.7003	30.44584	-86.46613
24-Nov	20:28:37	178444.9531	-0.508089	2.778083	-29.724934	-9.525223	-19.5159	-29.3888	30.46243	-86.45219
24-Nov	16:42:35	76745.78906	0.500232	2.696699	32.021576	9.692636	19	-32.0216	30.46225	-86.45209
22-Nov	22:19:59	4537.536133	-0.594405	2.635368	8.206122	-11.30595	19	-8.20612	30.45038	-86.45222
22-Nov	18:52:03	7128.737793	-0.249902	2.611277	7.189379	-12.926771	-18.5977	8.173909	30.46022	-86.46600
21-Nov	21:47:11	15390.76758	-0.844038	2.573352	3.205806	-16.147736	19.17734	-1.87262	30.46593	-86.46517
22-Nov	23:36:41	973.29071	-0.76178	2.567227	0.726046	-10.454065	19.01376	-0.06251	30.46430	-86.44774
21-Nov	15:48:00	10731.24121	-0.0207	2.555083	-6.623776	-13.228711	18.88151	6.954363	30.45126	-86.46697
21-Nov	14:54:09	8239.15332	-0.756337	2.54138	-5.862208	-8.965496	5.097032	19.21941	30.47304	-86.47417
21-Nov	14:49:45	740979.9375	0.21117	2.537044	-17.116594	-34.481602	-21.9237	13.16538	30.47723	-86.47244
22-Nov	19:07:09	15678.37109	-0.735133	2.534276	8.026433	-13.284175	18.39382	-9.33225	30.45788	-86.44526
22-Nov	19:47:41	8403.699219	-0.416143	2.523326	13.377182	-10.791091	20.29421	-11.3179	30.45724	-86.45590
21-Nov	21:56:40	2825.25708	-0.938578	2.460069	3.671743	-13.155036	-19.0612	3.339588	30.46762	-86.46515
21-Nov	17:54:01	6418.960937	-0.120641	2.443419	-11.963622	-16.344841	18.5709	12.61942	30.44549	-86.46542
22-Nov	20:06:10	2772.632568	-0.25871	2.432954	2.854994	-12.540903	-19.0881	2.190164	30.45492	-86.45915
22-Nov	23:41:58	12523.24902	-0.955134	2.401611	-12.429779	-8.384764	19.21404	12.09629	30.46438	-86.45763
22-Nov	20:43:41	20780.33789	0.050943	2.396009	11.129927	-12.299569	-19.5565	10.12029	30.45447	-86.46046
24-Nov	20:25:12	35421.21094	-0.277526	2.383821	-19.69878	-11.286084	-9.79267	-25.5567	30.46239	-86.45840
21-Nov	18:27:49	8982.136719	-0.296014	2.346166	-5.888747	-16.713432	18.89433	6.219446	30.44491	-86.46530
22-Nov	21:22:12	9206.103516	-0.793449	2.343662	-10.207643	-13.14659	-17.6144	-12.4471	30.45377	-86.46860
22-Nov	23:45:43	93846.28125	-0.591923	2.332167	17.763317	-15.916918	19.90362	-16.7446	30.46410	-86.46475
21-Nov	20:23:08	9763.754883	0.238417	2.282584	-15.94286	-15.372301	-19.5448	-15.2701	30.46936	-86.44666
21-Nov	21:57:11	22859.6875	-0.989484	2.223682	-9.80406	-16.022104	-16.5464	-13.5401	30.46764	-86.46416
22-Nov	21:39:40	260140.2344	-0.437831	2.199155	37.33894	-12.028691	19	-37.3389	30.45549	-86.44633
22-Nov	17:12:19	16124.72266	-0.505452	2.189914	6.642094	-12.440958	-19	6.642094	30.46234	-86.44920
22-Nov	19:17:23	3691.165283	-0.757396	2.185623	0.330408	-13.18854	19.00287	0.001238	30.45793	-86.46561
22-Nov	18:54:56	15726.70117	0.170486	2.182924	-11.765416	-13.537157	-19.5897	-10.7549	30.46019	-86.46040
22-Nov	23:12:32	10392.05273	-0.394871	2.163919	1.824118	-12.886556	16.61543	-9.39441	30.46440	-86.47362
21-Nov	21:57:10	11404.03223	-0.350474	2.129326	5.854508	-13.855014	-19.728	2.466249	30.46768	-86.46420
22-Nov	23:21:10	12517.07422	-0.422615	2.118963	9.377291	-11.338538	-18.4832	10.35882	30.46255	-86.46128

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
24-Nov	20:10:53	33064.55469	-0.449817	2.116439	-6.629931	-10.181569	-19.3209	-5.62646	30.46221	-86.44910
21-Nov	21:13:42	9667.911133	-0.951244	2.11461	4.493985	-13.733234	19.07554	-4.1617	30.46657	-86.46641
21-Nov	20:50:44	8015.103516	-0.127742	2.09731	-11.678249	-11.287179	-17.9099	-13.2898	30.46882	-86.46006
21-Nov	16:25:52	11379.60156	-0.991957	2.092567	8.445477	-14.268987	19.88762	-6.06701	30.45052	-86.47195
21-Nov	21:22:36	27290.40039	-0.810296	2.056948	2.564481	-16.704016	-19.1512	0.898763	30.46821	-86.46504
21-Nov	17:46:30	4444.759277	0.158347	2.035665	8.656529	-16.508348	19.42701	-7.65028	30.44552	-86.45055
21-Nov	14:56:39	1468.342651	-0.336109	2.027461	-5.312038	-5.196455	-6.29914	18.69595	30.46931	-86.47584
24-Nov	19:51:24	268462.1563	0.171576	2.026943	23.72447	-4.630932	-28.685	10.05103	30.46120	-86.47377
22-Nov	21:03:50	3782.944092	-0.207392	2.026812	-9.295321	-11.500675	18.48748	10.27697	30.45622	-86.44924
22-Nov	20:30:39	2480.556641	-0.807993	2.019081	-0.940922	-13.375853	19.01353	0.609183	30.45680	-86.46836
22-Nov	19:24:39	15325.46387	-0.451729	2.000798	-6.244543	-9.964928	-19.1061	-5.912	30.45960	-86.47003
24-Nov	16:48:31	3549.699219	-0.295481	1.991807	0.516722	-9.673884	-17.4382	-7.56144	30.46193	-86.45787
21-Nov	22:21:21	18346.19141	-0.885035	1.971667	4.791184	-17.237728	19.28793	-3.45414	30.46539	-86.46565
21-Nov	20:14:48	26827.80273	-0.230571	1.960912	17.802891	-12.664342	-19.3078	17.46858	30.46945	-86.46256
21-Nov	21:47:38	12275.18066	-0.897385	1.919333	9.019032	-15.115163	18.8397	-9.34925	30.46586	-86.46605
21-Nov	20:57:51	4224.694336	0.254797	1.883471	-2.097588	-14.716495	-19.1152	-0.10006	30.46878	-86.44650
22-Nov	18:17:15	89690.91406	-0.282548	1.876571	33.174015	-11.613286	-17.2378	34.12293	30.46079	-86.46220
22-Nov	19:27:57	28861.35156	0.044224	1.867516	8.468908	-11.998456	-19.6658	6.780722	30.45967	-86.46330
19-Nov	19:24:16	23.135246	0.205676	1.860265	-0.959683	-0.29363	-18.6678	3.66534	30.46986	-86.47047
22-Nov	17:35:49	9233.487305	-0.437155	1.847394	6.618406	-14.180718	-19	6.618406	30.46120	-86.47087
22-Nov	23:37:29	7299.293457	-0.390152	1.847248	-12.111492	-10.008304	18.56574	12.7672	30.46430	-86.44928
22-Nov	18:09:04	3950.748047	-0.569682	1.820486	4.932704	-10.03414	19.35761	-3.25797	30.45909	-86.47230
22-Nov	17:44:04	13786.53027	0.492601	1.809152	-14.557593	-11.288615	-20.1965	-12.8462	30.46125	-86.45550
19-Nov	19:26:50	31920.08398	-0.41962	1.788988	-2.798234	-12.458282	-18.8908	-3.45962	30.46971	-86.46550
24-Nov	20:18:42	154164.3906	-0.49045	1.779695	-32.977234	-9.561384	19	32.97723	30.46242	-86.45223
22-Nov	23:20:34	10894.3291	-0.875542	1.777222	-7.990226	-13.157406	-19	-7.99023	30.46252	-86.46250
22-Nov	22:35:44	111568.7734	-0.943798	1.765319	24.335291	-16.48307	-21.0487	22.58673	30.45264	-86.46896
21-Nov	17:10:20	21284.95117	-0.996599	1.764426	-17.18755	-16.158451	18.07443	18.15838	30.45013	-86.45561
22-Nov	21:29:30	27399.38086	-0.39435	1.763741	23.309109	-10.753144	-17.3278	24.5777	30.45383	-86.45481
23-Nov	0:13:46	5504.683594	-0.596689	1.753461	9.26918	-10.028922	19.15888	-8.93617	30.46265	-86.45238
21-Nov	21:03:01	107249.25	0.140332	1.731551	-1.274281	-15.232658	18.99244	-1.38241	30.46631	-86.44557
24-Nov	19:51:17	1008135.25	0.040454	1.730003	-39.085625	-11.243194	8.348242	-42.6497	30.46095	-86.47383
22-Nov	23:12:55	10441.00781	0.523242	1.72884	-8.908238	-13.428958	17.16445	12.07222	30.46453	-86.47432
22-Nov	22:33:51	4875.649414	-0.537749	1.726177	6.047636	-13.425202	-19.5281	4.028466	30.45250	-86.47257
22-Nov	18:18:52	6826.199707	-0.266778	1.714887	-4.71563	-13.005378	-19.2827	-3.37877	30.46062	-86.45900

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
21-Nov	20:46:19	56173.75	0.058482	1.703697	32.181942	-16.228369	-23.294	29.22446	30.46873	-86.46832
21-Nov	15:46:26	10327.1543	-0.129279	1.680198	10.031007	-17.134521	19.49894	-9.02288	30.45118	-86.46383
21-Nov	15:58:16	7767.698242	-0.913329	1.675674	13.816796	-13.776436	-17.4517	15.72715	30.44900	-86.46484
24-Nov	16:27:35	32308.90625	-0.462305	1.626312	4.811862	-17.21167	-19.1564	4.14584	30.46259	-86.46222
21-Nov	17:47:53	14949.45898	-0.728905	1.617789	19.19129	-16.967356	19.33204	-18.8568	30.44546	-86.45331
19-Nov	19:31:20	25318.49414	-0.094708	1.61531	-1.78591	-0.984118	-19.0674	-0.78908	30.46969	-86.45685
21-Nov	20:03:31	1518.706055	-0.591874	1.598644	-0.203917	-9.496113	-3.0985	-18.7468	30.45687	-86.47191
22-Nov	23:21:12	8473.112305	0.093362	1.563972	-0.615134	-11.00816	-19.0062	0.380092	30.46252	-86.46122
22-Nov	22:00:56	8327.015625	-0.781596	1.559658	16.363821	-15.366659	-19.2827	16.02973	30.45320	-86.46356
22-Nov	19:54:56	6321.02832	-0.137632	1.546477	9.122765	-11.557468	19.15632	-8.78978	30.45735	-86.46954
24-Nov	16:31:50	1895.439209	-0.324397	1.542303	-7.037922	-10.600809	-18.8743	-7.36845	30.46252	-86.45435
21-Nov	15:47:20	12617.69336	-0.753669	1.525118	14.358322	-13.967153	18.48733	-15.0127	30.45118	-86.46564
24-Nov	16:52:25	43589.72266	-0.244312	1.524994	-16.749174	-9.385858	-20.1221	-15.383	30.46223	-86.45092
22-Nov	23:54:31	30553.07227	-0.933094	1.507218	14.327656	-13.229959	-22.4976	7.755088	30.46271	-86.46853
21-Nov	18:55:34	6582.375488	-0.411126	1.506317	-16.050217	-16.117062	-18.4283	-16.7035	30.44657	-86.45123
24-Nov	16:52:18	588.279846	-0.774153	1.489015	4.064708	-9.429611	-18.8466	4.725322	30.46230	-86.45113
21-Nov	19:45:15	90530.1875	-0.969221	1.485056	-35.863823	-25.439362	19	35.86382	30.44382	-86.45284
22-Nov	22:03:27	148034.9531	-0.820731	1.479905	9.724278	-12.826982	-19.1668	9.391201	30.45323	-86.45891
22-Nov	18:49:38	6883.675781	-0.5438	1.473323	2.785737	-12.511203	-19.0856	2.12095	30.46008	-86.47072
22-Nov	18:33:10	22027.55664	0.214914	1.441151	21.558893	-10.718031	19.74082	-20.8827	30.45839	-86.44982
24-Nov	20:08:13	2115.751709	-0.014925	1.437134	-5.015771	-10.02862	-19.0846	-4.68341	30.46230	-86.45439
19-Nov	19:29:06	2.221151	-0.047341	1.433299	0.171215	0.108407	-18.9138	-1.81576	30.46973	-86.46112
22-Nov	20:02:15	21021.37891	-0.242733	1.432519	-17.015291	-16.066956	-19	-17.0153	30.45479	-86.46691
21-Nov	22:02:37	1696.297852	-0.712154	1.418264	-4.273047	-11.483516	-18.9225	-4.60399	30.46770	-86.45374
22-Nov	23:46:36	3143.706787	-0.018711	1.409564	3.545986	-12.134075	18.86467	-4.20692	30.46425	-86.46654
24-Nov	16:35:39	60177.51172	-0.153989	1.402814	20.394487	-10.771965	-27.8736	0.013286	30.46346	-86.44772
21-Nov	18:27:44	7390.150879	-0.519728	1.397737	4.307769	-16.799953	19.30315	-2.63542	30.44489	-86.46512
22-Nov	23:20:35	17469.42969	-0.548236	1.385653	-18.175203	-11.568483	-18.6799	-18.504	30.46249	-86.46246
22-Nov	23:25:49	117060.2266	-0.370358	1.376933	37.505013	-5.414524	-19	37.50501	30.46263	-86.45183
24-Nov	20:40:18	169378.9844	-0.622043	1.366756	-39.204613	-13.438345	20.35665	38.51764	30.46263	-86.45279
21-Nov	18:53:39	12449.72852	-0.276784	1.354266	3.169676	-15.487868	-18.8778	3.830836	30.44663	-86.45490
22-Nov	23:21:11	3349.954834	-0.066107	1.349713	-2.089739	-8.356676	-19.0995	-0.75928	30.46252	-86.46125
22-Nov	17:54:36	1977.040283	-0.948285	1.34518	-4.095744	-12.69177	18.84549	4.756339	30.45908	-86.44614
22-Nov	23:58:17	13036.01758	0.211253	1.341026	10.94229	-12.280523	-18.6065	11.59871	30.46247	-86.46117
22-Nov	18:42:00	1250.623169	0.855261	1.333523	2.284145	-12.06068	19.03697	-1.9522	30.45848	-86.46635

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	23:07:33	53469.13281	-0.91735	1.31798	-18.556154	-19.080935	17.65931	19.83633	30.46373	-86.46461
23-Nov	0:15:56	20329.4375	0.580018	1.311422	13.667149	-12.142284	10.35967	-20.9873	30.46353	-86.45622
21-Nov	18:08:03	9678.689453	-0.991313	1.310008	9.773424	-18.647873	-18.6473	10.43056	30.44721	-86.45782
22-Nov	18:40:52	1467.148193	0.073581	1.309393	-4.57513	-13.021562	19.07695	4.242837	30.45848	-86.46428
21-Nov	17:32:32	8519.980469	-0.409926	1.307891	7.632449	-14.955063	-19	7.632449	30.44779	-86.45657
21-Nov	14:54:12	12125.27441	-0.066154	1.299484	7.06533	-10.028943	16.06021	12.36886	30.47296	-86.47419
22-Nov	18:42:09	747.592529	-0.168463	1.29611	5.046076	-12.005402	18.81232	-5.70609	30.45847	-86.46663
22-Nov	19:08:25	1415988.75	0.445916	1.29009	-54.903217	-17.926094	21.84737	53.83359	30.45805	-86.44777
22-Nov	17:03:33	36160.23828	0.19545	1.27474	-7.756194	-14.620687	-15.2014	-13.7868	30.46075	-86.46560
21-Nov	17:07:51	10839.90723	-0.698756	1.258293	-19.999496	-16.360746	17.92727	20.96647	30.45019	-86.45086
21-Nov	15:49:02	15695.58594	-0.752945	1.245052	-7.486735	-17.397827	18.86644	7.81719	30.45128	-86.46904
22-Nov	20:03:10	3989.550781	-0.690385	1.244989	-1.928641	-14.026793	-18.9211	-2.59056	30.45487	-86.46508
22-Nov	19:26:09	21936.01172	-0.735242	1.243527	-17.389961	-11.809291	-18.0638	-18.3605	30.45956	-86.46696
22-Nov	21:48:22	6777.805176	-0.643548	1.242617	-6.786637	-15.636087	18.75158	7.445593	30.45564	-86.46315
22-Nov	22:36:12	1919.187744	-0.974809	1.231857	-0.834673	-13.959924	-18.9303	-1.82791	30.45267	-86.46809
21-Nov	21:42:40	3326.106689	0.839067	1.226279	-5.922408	-8.140368	19	5.922408	30.46599	-86.45626
22-Nov	19:36:52	1917.638428	-0.382574	1.22306	-4.624791	-11.890572	-19.0778	-4.29249	30.45960	-86.44543
21-Nov	16:05:05	5270.631836	0.154202	1.220777	-4.313478	-13.39399	-18.445	-6.27589	30.44892	-86.45153
21-Nov	19:41:04	7105.519531	0.114917	1.19893	-13.249068	-14.636061	19	13.24907	30.44373	-86.44471
21-Nov	21:52:24	15366.11719	-0.503757	1.197872	3.165498	-14.529167	-19.0483	-2.86076	30.46752	-86.47322
24-Nov	19:44:30	13374.69238	0.317407	1.192911	-11.886391	-19.173784	22.38164	-1.16119	30.45111	-86.47171
21-Nov	20:57:53	10684.02441	0.390302	1.189784	-12.757546	-15.081651	-20.2294	-10.7016	30.46874	-86.44644
22-Nov	18:56:17	13556.9834	-0.204442	1.189553	4.6	-11.371376	-19	4.6	30.46009	-86.45780
22-Nov	18:07:08	110243.5703	0.546016	1.188571	20.65575	-9.831864	17.89292	-21.6218	30.45905	-86.46865
22-Nov	21:16:56	7330.337402	-0.503541	1.183914	-12.159011	-10.611362	22.48431	1.81581	30.45643	-86.47341
22-Nov	18:31:01	2154.714355	-0.996969	1.178902	0.100821	-13.482003	19	-0.10082	30.45845	-86.44568
21-Nov	16:13:51	14217.80273	0.300661	1.174546	24.82547	-13.197995	16.30095	-26.6755	30.45064	-86.44765
21-Nov	20:12:32	46009.82422	-0.981876	1.162566	12.99714	-17.561483	-20.0605	11.29172	30.46938	-86.46689
22-Nov	22:31:40	11603.05469	0.476036	1.151649	9.736127	-14.288466	5.837416	-20.5357	30.45074	-86.47491
22-Nov	17:32:09	17816.71484	-0.790909	1.150991	14.454478	-15.652025	23.08785	6.073139	30.46552	-86.47289
24-Nov	20:19:13	2679.702881	-0.265787	1.150864	0.978996	-14.794003	18.98002	-1.31044	30.46231	-86.45322
21-Nov	17:20:20	23133.5957	0.312501	1.12492	-7.248725	-21.734362	19.45936	5.905694	30.45052	-86.47455
24-Nov	20:09:18	136208.8594	-0.786154	1.120222	33.101074	-9.695955	-20.1436	32.41782	30.46244	-86.45225
22-Nov	17:27:37	31289.92188	-0.920906	1.117103	-3.90597	-16.217218	16.38077	-10.3888	30.46629	-86.46445
22-Nov	22:43:46	1141.912231	-0.432915	1.104656	-1.057775	-12.797746	-19	-1.05778	30.45265	-86.45389

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
24-Nov	16:24:03	2862.621094	-0.558696	1.104331	1.813806	-17.021986	-11.3656	15.33342	30.46481	-86.46768
21-Nov	16:34:21	13590.01172	-0.831883	1.10383	-10.593464	-21.334822	-18.0044	-12.2091	30.44824	-86.46205
22-Nov	22:28:33	38481.375	0.275406	1.101552	-28.935236	-14.650803	20.48831	27.9012	30.45041	-86.46913
21-Nov	21:07:25	729.963867	0.165958	1.094806	-3.644408	-9.132706	18.78323	4.633797	30.46657	-86.45406
19-Nov	19:24:34	6021.09375	-0.087322	1.08435	-0.718497	-0.626729	-18.9903	0.940196	30.46976	-86.46990
22-Nov	17:19:55	268485.4688	-0.427392	1.076042	-35.176353	-11.266837	17.13297	36.12253	30.46244	-86.45222
22-Nov	19:32:30	820.384949	-0.979316	1.065687	3.833113	-9.710056	-19.064	3.500933	30.45958	-86.45417
22-Nov	21:58:18	77755.60938	-0.8499	1.061372	30.834326	-15.510209	-20.5877	29.79769	30.45326	-86.46854
23-Nov	0:10:32	17146.10352	0.132084	1.054558	-17.982098	-17.379908	21.04984	15.53254	30.46272	-86.44627
24-Nov	16:43:10	3651.343262	-0.960338	1.046839	-1.796179	-17.235741	18.77115	3.445303	30.46232	-86.45322
24-Nov	16:26:56	12251.95606	-0.319165	1.041748	17.14982	-12.588484	-20.4224	15.4286	30.46260	-86.46343
22-Nov	19:18:25	4814.794434	-0.643366	1.025394	-17.081909	-10.948318	19.58458	16.40841	30.45798	-86.46764
22-Nov	20:20:08	36068.36719	-0.259591	1.021163	8.920712	-12.009211	17.96345	-10.8579	30.45672	-86.44878
23-Nov	0:05:39	2269.38501	-0.853134	1.018319	9.492022	-8.710711	-16.1393	13.80658	30.46244	-86.44656
21-Nov	19:35:20	7110.209961	-0.873268	1.013806	20.92111	-14.658746	-19.3622	20.58633	30.44603	-86.44852
21-Nov	20:38:04	14114.2627	-0.873063	1.012418	-20.512072	-14.391833	17.90044	21.47834	30.46712	-86.46541
22-Nov	17:18:51	1474.749756	-0.671919	1.011764	0.637856	-8.913937	19.00734	0.357401	30.46233	-86.45023
21-Nov	16:01:05	45423.69531	-0.848767	1.009171	11.090372	-30.937891	-18.6014	11.74671	30.44893	-86.45937
22-Nov	23:50:25	8474.017578	-0.406978	1.007592	7.556802	-10.761491	19.29719	6.761931	30.46393	-86.47407
22-Nov	19:32:26	113213.7734	-0.390879	1.00549	29.760969	-9.450914	-20.0271	29.07975	30.45965	-86.45430
22-Nov	20:41:46	34881.14063	-0.470368	1.00017	5.204595	-16.793993	-19.5803	2.168263	30.45429	-86.46424
21-Nov	17:37:28	435.441467	0.498667	0.999553	-3.785195	-13.415575	-18.5978	-5.42675	30.44772	-86.44694
22-Nov	20:00:01	28912.57422	-0.503663	0.997469	17.755827	-12.961334	-21.2862	14.93874	30.45489	-86.47137
22-Nov	21:24:29	18402.30859	-0.965526	0.995886	9.498549	-14.911144	-19	9.498549	30.45377	-86.46422
22-Nov	21:49:12	28166.79102	-0.833701	0.96682	-13.997291	-20.176226	18.75282	14.32675	30.45566	-86.46468
22-Nov	21:23:55	1686.143188	0.259247	0.963244	2.438349	-12.439563	-19.0397	2.106382	30.45375	-86.46530
22-Nov	23:01:30	5428.382812	-0.224761	0.947962	-14.443348	-8.275219	19.49249	13.77146	30.46374	-86.45311
24-Nov	16:27:37	11531.09766	0.345727	0.943978	-7.971914	-13.93522	-19.1362	-7.6391	30.46256	-86.46216
22-Nov	21:58:11	24880.33203	-0.882343	0.938558	-20.464117	-16.243353	-20.3812	-19.0889	30.45312	-86.46876
22-Nov	22:43:33	5810.937012	-0.694534	0.934915	5.817135	-15.506194	-19	5.817135	30.45270	-86.45429
24-Nov	16:32:59	159392.1094	-0.553183	0.933219	-35.183197	-8.991244	-20.2163	-34.4987	30.46243	-86.45222
22-Nov	18:02:53	1198.474731	0.690234	0.930629	-0.374099	-13.987376	18.99058	0.705638	30.45907	-86.46118
21-Nov	20:38:40	11889.01563	-0.695652	0.913699	-10.751541	-12.378793	19.70371	9.399978	30.46716	-86.46655
22-Nov	18:59:17	6561.486816	-0.442735	0.913268	4.426876	-14.305808	-19	4.426876	30.46017	-86.45206
23-Nov	0:03:16	169524.0938	-0.413934	0.910531	-33.082066	-12.186145	-20.7053	-32.0423	30.46242	-86.45125

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	21:24:17	106210.4688	-0.862476	0.899792	-22.780336	-20.575504	-19	-22.7803	30.45369	-86.46459
22-Nov	22:40:21	1284.123413	-0.382958	0.893236	7.1047	-11.806031	-18.8731	7.435214	30.45273	-86.46028
22-Nov	18:05:28	968.568604	-0.125555	0.892349	6.406343	-12.564075	18.63868	-7.39195	30.45911	-86.46574
22-Nov	23:59:48	7198.679687	0.272238	0.890956	-14.983112	-10.464433	-18.1898	-15.957	30.46252	-86.45816
22-Nov	22:34:02	4972.986816	-0.507043	0.886837	11.227183	-12.446012	-19.193	10.89388	30.45253	-86.47218
22-Nov	18:48:16	11745.04297	-0.707553	0.880738	-8.993291	-10.713215	-20.7429	-3.4078	30.46036	-86.47330
21-Nov	20:39:28	320.9263	-0.219196	0.877931	3.894023	-10.094335	19.17776	-2.8943	30.46713	-86.46808
21-Nov	18:27:21	18919.83789	-0.752517	0.868591	27.355272	-14.193446	20.40563	-26.3234	30.44489	-86.46437
21-Nov	21:11:57	28533.2793	-0.304993	0.861511	-5.974603	-12.871233	19.10138	5.642097	30.46655	-86.46297
21-Nov	14:53:26	3753.506348	0.50446	0.858532	-7.797224	-13.553784	2.747406	20.35309	30.47400	-86.47358
22-Nov	22:36:38	1137.461792	0.475716	0.844876	8.30257	-12.720251	-18.8522	8.632901	30.45270	-86.46729
22-Nov	19:16:25	837.984619	-0.332455	0.84327	-8.214069	-10.9104	19.6436	6.526853	30.45793	-86.46370
22-Nov	19:52:45	4306.836426	-0.599129	0.839943	1.412378	-13.557936	19.05224	-0.08356	30.45730	-86.46548
22-Nov	23:10:47	669.205688	-0.109677	0.837271	-4.733069	-11.438493	18.62355	6.046912	30.46366	-86.47071
21-Nov	15:03:12	47590.80078	-0.865996	0.835763	7.465096	-23.606955	-20.4064	-0.55223	30.46656	-86.46567
21-Nov	21:16:11	37400.44922	-0.920866	0.833695	23.486023	-9.288162	19	-23.486	30.46643	-86.47127
21-Nov	15:11:31	394046.5313	-0.454093	0.830641	13.112853	-9.544314	23.08511	0.156532	30.45974	-86.47280
21-Nov	17:19:49	7298.489258	-0.50395	0.830119	6.603439	-16.750187	17.02758	-10.7083	30.45031	-86.47362
21-Nov	20:03:05	14387.99023	-0.00203	0.829315	-3.832596	-10.453901	-1.21556	-19.3445	30.45587	-86.47214
22-Nov	19:56:22	6665.777832	-0.559404	0.828749	12.097116	-11.867141	19.79757	-10.7423	30.45732	-86.47219
22-Nov	19:07:56	529.382996	-0.794709	0.813992	-2.591585	-10.469252	18.77294	3.910645	30.45791	-86.44682
22-Nov	19:54:46	7155.628418	0.014201	0.813213	22.563517	-13.9514	19.77588	-21.8867	30.45731	-86.46923
24-Nov	20:36:19	9662.34375	0.297448	0.812578	-13.909518	-12.262452	20.55352	11.49032	30.46237	-86.44543
22-Nov	23:10:06	2681.985352	-0.202091	0.809969	9.006331	-12.28214	19.95597	-6.62368	30.46372	-86.46942
22-Nov	22:01:44	660.540771	-0.309153	0.801688	-1.664301	-11.647352	-18.9681	-1.99564	30.45319	-86.46207
21-Nov	21:03:00	12314.31055	-0.03361	0.793344	-2.164229	-14.125281	19.1163	-0.50112	30.46630	-86.44554
22-Nov	19:53:08	12713.55176	-0.550262	0.791669	3.788502	-22.638115	18.85621	-4.44928	30.45729	-86.46621
22-Nov	21:14:39	18597.94531	-0.500668	0.789413	-21.491377	-14.109015	18.62203	21.8197	30.45629	-86.46925
22-Nov	23:26:05	110040.5625	-0.468557	0.789182	-36.368893	-8.694089	-21.4907	-34.9549	30.46242	-86.45130
22-Nov	21:44:02	1522.285156	-0.857392	0.788662	-6.087082	-11.755104	19.20086	5.420283	30.45560	-86.45501
22-Nov	17:27:33	3811.923828	-0.901824	0.779771	8.672742	-11.332568	5.217101	-20.2237	30.46617	-86.46439
22-Nov	19:25:21	16235.39844	-0.572821	0.776168	21.143627	-9.188704	-19.3661	20.80881	30.45965	-86.46859
21-Nov	22:16:26	525.414246	-0.976938	0.774343	-3.091613	-8.111202	18.88053	3.75282	30.46546	-86.45597
24-Nov	19:47:53	572.266357	-0.339314	0.773014	-2.662287	-10.425201	2.662287	-19	30.45548	-86.47453
22-Nov	21:13:33	18372.50391	-0.924056	0.772725	23.497013	-12.851907	17.31465	-24.7651	30.45614	-86.46730

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
21-Nov	20:22:47	1386.61145	0.633443	0.7717	7.362644	-13.425659	-19.4673	6.019336	30.46942	-86.44734
24-Nov	20:05:36	1583.747925	-0.852734	0.770039	-9.649055	-13.059548	-18.469	-10.6302	30.46227	-86.45957
24-Nov	16:27:37	12231.66406	-0.550762	0.763696	-2.948709	-16.720486	-19.0486	-2.61666	30.46257	-86.46216
22-Nov	18:48:22	10560.20117	-0.665967	0.763562	-10.467755	-10.014564	-21.3728	-3.71166	30.46031	-86.47313
22-Nov	21:56:43	2200.123291	-0.915588	0.762711	2.029201	-14.218001	-19.0592	1.364874	30.45326	-86.47157
21-Nov	17:08:01	7302.23877	-0.110231	0.760951	15.324983	-15.400739	19.77601	-14.3096	30.45009	-86.45118
21-Nov	19:12:31	13149.27344	-0.26072	0.754827	-19.729708	-19.181826	19.67698	19.0546	30.44437	-86.46230
22-Nov	22:43:08	1308.824341	-0.775929	0.752457	-0.201657	-14.074118	-18.9814	-0.86462	30.45270	-86.45506
23-Nov	0:03:00	157091.0313	-0.246125	0.750934	40.849064	-6.78017	-18.2842	41.17444	30.46264	-86.45177
22-Nov	21:17:03	44320.60938	-0.414744	0.749038	-14.229917	-12.737745	22.72108	6.873365	30.45651	-86.47362
21-Nov	21:57:07	31827.29102	-0.921813	0.748549	21.763128	-14.099904	-22.8035	17.73791	30.46771	-86.46431
24-Nov	20:28:42	55506.38281	-0.912256	0.747593	-22.965771	-9.404303	-18.5963	-23.2939	30.46244	-86.45203
22-Nov	20:27:52	846.130676	0.550866	0.746601	2.649302	-13.450649	18.95087	-2.98049	30.45680	-86.46320
21-Nov	21:17:13	2728.476318	-0.497619	0.744835	5.3306	-11.971637	9.96451	-17.033	30.46692	-86.47316
22-Nov	22:48:06	1129.365601	-0.349897	0.74114	-3.441376	-13.301866	-18.8683	-4.10237	30.45262	-86.44547
24-Nov	16:32:32	2479.255615	0.22559	0.738989	-2.772437	23.684517	-18.8917	-3.43384	30.46251	-86.45306
24-Nov	20:09:58	36080.91406	-0.300953	0.738456	-31.428202	-10.194255	-22.1811	-29.27	30.46222	-86.45093
21-Nov	22:21:03	1720.234375	-0.732868	0.734782	3.87871	-14.104579	19.33107	-1.53428	30.46548	-86.46507
22-Nov	18:34:37	177609.5156	-0.751094	0.731703	-49.049068	-20.275688	16.40693	49.97623	30.45854	-86.45259
21-Nov	16:02:01	3919.791504	-0.806267	0.731376	-9.455788	-16.924362	-17.9075	-11.39	30.44892	-86.45755
22-Nov	23:58:18	3131.788818	-0.102153	0.729572	8.916427	-12.241125	-19.2996	8.247905	30.46246	-86.46113
22-Nov	22:23:09	30832.53906	-0.216181	0.729526	-20.965525	-30.668304	19.36301	20.63074	30.45048	-86.45855
19-Nov	19:20:12	0.817532	-0.077746	0.724065	0.170218	-0.109968	6.650079	-17.799	30.47175	-86.46777
22-Nov	23:02:55	994.941711	-0.89337	0.719583	5.193428	-8.746963	19	-5.19343	30.46367	-86.45581
22-Nov	21:44:22	778.652405	-0.523922	0.713935	0.796293	-12.624208	18.98321	-1.12777	30.45558	-86.45564
22-Nov	22:00:16	5228.123047	-0.065871	0.707493	4.090859	-13.634778	-18.8457	4.751457	30.45321	-86.46482
22-Nov	22:19:25	12279.99707	-0.968144	0.70587	12.701231	-23.553371	19.43169	-12.0304	30.45037	-86.45109
21-Nov	22:21:23	4053.262939	-0.896388	0.705277	-5.684953	-16.237541	18.43222	7.319279	30.46542	-86.46571
21-Nov	22:10:20	399823.625	-0.886285	0.705195	-16.910267	-41.229908	21.64778	13.35405	30.46530	-86.44407
19-Nov	19:29:06	70998	0.128119	0.704278	20.911385	-11.443491	-21.0818	18.81079	30.46979	-86.46113
22-Nov	19:52:44	2722.816162	-0.477822	0.703402	9.059319	-11.465408	19.58566	-7.71188	30.45728	-86.46545
21-Nov	20:47:58	1668.562256	-0.307062	0.69649	6.968153	-13.938448	-19.2316	6.300818	30.46885	-86.46527
24-Nov	16:30:53	825.545837	0.163573	0.695103	-2.497696	-12.919179	-18.9535	-2.82891	30.46253	-86.45610
22-Nov	22:27:52	89885.46875	0.079131	0.692467	-61.177368	-12.326142	21.12349	60.47701	30.45051	-86.46780
22-Nov	22:43:39	2059.91333	-0.728208	0.688863	2.914911	-12.212847	-18.8214	3.905299	30.45266	-86.45411

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	22:42:07	973.585876	0.351126	0.674266	-4.761011	-11.970409	-18.3983	-6.72097	30.45266	-86.45696
21-Nov	19:41:31	612.382202	-0.05458	0.673871	-5.480544	-14.765094	19.26079	4.47865	30.44371	-86.44568
24-Nov	16:29:55	61847.08984	0.941437	0.670698	-28.075729	-24.046082	-19	-28.0757	30.46243	-86.45789
24-Nov	16:23:38	18673.72852	-0.88325	0.669924	21.608274	-22.842991	3.344595	28.57851	30.46535	-86.46818
22-Nov	18:40:39	200074.9375	-0.527831	0.666538	-55.95871	-15.309968	21.90261	54.88764	30.45862	-86.46386
22-Nov	17:20:28	2543.29541	-0.542872	0.66613	-6.056164	-12.272666	19.1028	5.723646	30.46234	-86.45324
21-Nov	21:08:36	9355.333008	-0.819631	0.664827	-19.391556	-9.540936	19	19.39156	30.46664	-86.45638
22-Nov	22:11:07	580.912476	-0.993861	0.664565	-2.843313	-13.338379	-18.5119	-5.13764	30.45315	-86.44420
22-Nov	21:50:39	1428.052856	-0.87982	0.663449	-6.838338	-17.39345	19	6.838338	30.45565	-86.46731
21-Nov	17:52:22	10275.99609	-0.214392	0.662617	-23.837784	-13.079747	16.8501	25.40303	30.44555	-86.46219
21-Nov	16:23:32	69661.08594	-0.515398	0.659613	8.804375	-16.088516	18.84345	-9.13463	30.45056	-86.46725
22-Nov	19:08:20	44861.88281	-0.346586	0.654287	-20.122416	-3.698889	19.69069	19.44707	30.45795	-86.44761
24-Nov	19:51:14	2109.644043	-0.843149	0.653133	-5.196283	-10.21015	-10.6428	-16.5751	30.46097	-86.47396
22-Nov	19:54:13	779.343628	0.069939	0.650832	-3.059899	-13.100647	19.1341	2.061322	30.45738	-86.46821
22-Nov	22:58:40	414.775269	-0.7552	0.648223	-0.873792	-9.800493	19.01236	0.542063	30.46370	-86.44757
21-Nov	14:55:10	1180.939575	-0.581835	0.641377	-5.40459	-7.155664	5.153086	19.06975	30.47165	-86.47520
24-Nov	16:33:34	4797.509766	-0.171168	0.639981	-18.615536	-10.625577	-21.127	-16.1613	30.46242	-86.45115
21-Nov	21:13:09	11198.27832	-0.947577	0.639111	-3.255148	-16.266317	19.18078	1.921846	30.46662	-86.46534
24-Nov	20:28:20	167230.5781	-0.284198	0.638957	48.212563	-6.50201	-20.671	47.5201	30.46265	-86.45271
21-Nov	20:44:48	633.737732	0.263303	0.637411	3.813493	-12.903519	-19.3709	-0.55832	30.46889	-86.47096
22-Nov	23:22:55	6012.04834	-0.282997	0.637286	16.621897	-7.969212	-20.3764	14.90269	30.46256	-86.45772
22-Nov	22:52:35	39200.33203	-0.65097	0.63707	19.483961	-23.105625	-23.2587	-14.1301	30.45806	-86.44064
22-Nov	17:37:27	12913.47168	0.134235	0.635871	22.691551	-11.134415	-20.9054	20.94924	30.46137	-86.46767
24-Nov	16:50:33	2458.928955	-0.052724	0.634575	13.246154	-11.041208	-19	13.24615	30.46230	-86.45435
22-Nov	23:58:15	9510.544922	-0.363656	0.633798	19.275267	-10.208649	-19	19.27527	30.46249	-86.46123
22-Nov	21:27:10	993.494995	-0.39472	0.632548	-0.185989	-12.312557	-18.9819	-0.84897	30.45373	-86.45922
22-Nov	23:03:44	2590.228271	-0.865329	0.632074	6.970097	-9.771585	19.23168	-6.30276	30.46364	-86.45736
22-Nov	22:10:59	886.361389	0.352117	0.631341	6.10252	-12.644135	-19.2014	5.435712	30.45317	-86.44446
22-Nov	20:31:30	995.644104	-0.387583	0.628547	9.034736	-11.136333	18.83943	-9.36496	30.45670	-86.47000
19-Nov	19:25:26	18617.14453	-0.847383	0.627244	4.109272	-18.067358	-19.1318	3.443678	30.46975	-86.46822
21-Nov	14:54:23	297955.0313	-0.683857	0.624922	-25.754023	-18.844265	-12.8036	29.33149	30.47275	-86.47447
22-Nov	21:42:53	55676.91406	-0.434778	0.623213	-37.113716	-11.540784	20.28368	36.42802	30.45566	-86.45282
22-Nov	23:14:46	738.5047	-0.238868	0.622903	-3.688582	-5.318342	-19.167	-2.68914	30.46235	-86.47411
21-Nov	17:13:52	12929.26856	0.312013	0.621674	-20.837051	-15.376589	19.71563	20.16127	30.45012	-86.46226
24-Nov	16:35:50	84138.96875	-0.722104	0.617734	-1.22948	-46.964001	-10.1732	-16.094	30.46364	-86.44744

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	17:28:33	1375.303223	-0.971751	0.617352	-1.215223	-12.043586	19.03849	-0.11311	30.46720	-86.46602
21-Nov	17:49:47	32778.0625	-0.604199	0.616359	28.647795	-14.645571	17.98863	-29.2934	30.44550	-86.45706
24-Nov	16:45:19	222.054092	-0.038994	0.614668	-6.44149	-9.107899	11.00643	16.77353	30.46080	-86.45692
22-Nov	23:12:07	16933.13867	-0.350002	0.613261	5.036656	-16.124807	11.03514	-16.2663	30.46397	-86.47308
19-Nov	19:19:01	29158.81445	-0.927861	0.611689	6.260723	-17.498896	-19.7152	-3.39207	30.47024	-86.46878
20-Nov	19:41:51	1.085462	-0.315735	0.609422	0.428806	-0.208198	14.40668	12.39482	30.45856	-86.44317
24-Nov	16:29:30	16634.23438	-0.709435	0.609206	28.826302	-15.996149	-18.494	29.15351	30.46260	-86.45866
22-Nov	18:47:59	27294.38086	-0.952635	0.606945	-5.726619	-12.426085	-16.3005	-11.3177	30.46035	-86.47379
22-Nov	21:01:58	1505.220093	-0.020482	0.606804	-4.318512	-13.972811	19.41611	1.632196	30.45615	-86.44543
22-Nov	17:30:42	1478.778687	-0.544769	0.605499	-8.68877	-12.97879	18.17042	10.31167	30.46681	-86.47044
21-Nov	20:45:38	4677.672363	-0.144554	0.599241	-8.443209	-15.518332	-20.1775	-5.01562	30.46865	-86.46953
21-Nov	19:05:08	258210.5938	-0.468862	0.594649	25.675627	-51.203259	19.44521	-25.3401	30.44427	-86.44761
21-Nov	21:15:14	799.584778	-0.19585	0.590392	2.488829	-12.173599	19.10422	-1.49103	30.46654	-86.46940
21-Nov	20:27:57	1528.035156	0.087055	0.589265	-4.95389	-14.179363	19.23323	3.952718	30.46708	-86.44616
22-Nov	17:25:56	524.502808	0.335756	0.588291	3.162636	-14.335728	10.9235	-15.8644	30.46393	-86.46221
22-Nov	18:55:36	1869.059937	-0.976238	0.585632	6.031106	-11.924633	-18.8918	6.361783	30.46015	-86.45911
22-Nov	21:06:35	364531.8125	-0.474018	0.584679	46.721581	-6.494443	14.01218	-48.4517	30.45605	-86.45444
22-Nov	23:55:47	510545.375	0.36207	0.58319	-26.653912	-13.585687	-23.7367	-22.5388	30.46239	-86.46611
22-Nov	22:41:21	5392.463867	-0.481538	0.577572	17.295931	-12.359411	-20.7038	15.21514	30.45270	-86.45840
24-Nov	16:34:25	760.321411	-0.543999	0.576568	-0.28497	-13.780337	-18.2788	-5.19282	30.46249	-86.44960
22-Nov	22:24:17	720.245667	-0.792049	0.575151	4.77689	-14.93237	19.34403	-3.10275	30.45039	-86.46080
22-Nov	22:00:12	9777.256836	-0.193608	0.574988	0.9696	-15.50526	-19	0.9696	30.45321	-86.46495
22-Nov	23:02:49	261139.2031	0.778707	0.574698	12.309424	8.125436	19	-12.3094	30.46365	-86.45562
21-Nov	17:13:21	83678.05469	-0.725986	0.57425	-23.164963	-36.726456	18.59282	23.49303	30.45018	-86.46129
22-Nov	20:47:16	2754.887695	-0.975178	0.569985	13.073427	-11.623091	-19.2253	12.73984	30.45433	-86.45347
21-Nov	20:38:42	2391.667725	-0.756745	0.569976	-0.788111	-11.255523	18.9783	-1.20225	30.46714	-86.46661
22-Nov	21:32:36	2895.249512	-0.24992	0.567994	-11.837276	-11.742806	-19.5935	-10.8267	30.45378	-86.44867
24-Nov	20:06:15	15277.42676	0.007391	0.567761	-23.63253	-11.360174	-19	-23.6325	30.46225	-86.45828
21-Nov	21:55:51	21580.2793	-0.143371	0.566661	-27.835135	-20.000624	-21.3537	-26.0733	30.46760	-86.46671
21-Nov	22:19:28	1213.401245	-0.691509	0.566084	-7.541234	-9.52359	19.12872	7.20849	30.46549	-86.46194
22-Nov	19:08:11	54017940	-0.697132	0.5615	52.791061	-56.958889	19	-52.7911	30.45775	-86.44731
21-Nov	15:31:09	1013.828125	0.019357	0.55878	7.836074	-13.351433	-18.715	8.494391	30.44957	-86.44997
22-Nov	17:36:25	63853.05469	-0.856927	0.556462	-4.81951	-24.228708	-17.8744	-8.04561	30.46126	-86.46969
22-Nov	21:15:17	11355.01758	-0.703481	0.55286	-22.334549	-15.212234	19	22.33455	30.45634	-86.47040
22-Nov	19:44:58	246.792145	-0.090418	0.55129	2.02589	-9.852541	19.05913	-1.36157	30.45723	-86.45067

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
21-Nov	17:46:32	416.700439	0.667615	0.54529	-3.138938	-14.075265	18.94232	3.470056	30.44555	-86.45061
22-Nov	23:02:49	1865086.5	-0.239957	0.543145	45.830425	0.23317	19	-45.8304	30.46356	-86.45562
21-Nov	19:43:13	128557.4375	0.820121	0.53856	48.161198	-8.491619	13.8617	-49.8834	30.44359	-86.44900
22-Nov	17:28:31	103161.9141	0.942487	0.538441	31.347382	6.020528	13.86227	-33.9337	30.46710	-86.46597
22-Nov	22:28:26	691.908936	0.454769	0.538384	13.705695	-11.20299	18.75791	-14.0352	30.45029	-86.46891
22-Nov	23:17:36	37720.30859	-0.804672	0.537006	16.233778	-12.630619	-21.5303	12.68784	30.46254	-86.46857
22-Nov	19:56:35	4969.165527	-0.866696	0.536226	-11.873613	-11.8019	18.78988	12.2034	30.45735	-86.47259
22-Nov	21:01:56	1385427.75	0.08587	0.532956	21.954449	-79.333511	17.01424	-23.5269	30.45607	-86.44537
22-Nov	21:50:04	2769.548584	-0.826081	0.528451	-5.166264	-19.262184	19	5.166264	30.45566	-86.46625
21-Nov	20:17:13	2172.157715	-0.6657	0.524214	11.201041	-11.798593	-19.7351	9.848383	30.46946	-86.45800
21-Nov	18:26:40	339464.8438	0.331943	0.523176	-60.147106	-15.683168	22.12182	59.07029	30.44509	-86.46300
22-Nov	19:56:48	20529.71484	-0.159223	0.521472	-23.811171	-9.187509	15.50122	26.22373	30.45736	-86.47300
22-Nov	21:14:06	1958.689941	0.341864	0.518235	9.987833	-15.731957	19.337	-9.31866	30.45623	-86.46827
24-Nov	19:45:09	5172.516602	-0.709178	0.516227	11.458061	-16.488165	10.38484	-19.6072	30.45167	-86.47278
21-Nov	21:34:05	13176.52148	0.115604	0.514071	-11.766134	-23.138447	-22.3375	-0.68977	30.46798	-86.44300
21-Nov	20:47:55	617.57666	-0.406889	0.510499	8.334593	-13.246702	-19.1426	8.001728	30.46885	-86.46536
22-Nov	23:14:38	5881.378906	-0.585455	0.509345	-10.537766	-8.253931	-20.8835	-5.99361	30.46238	-86.47439
24-Nov	20:17:39	1389.386597	-0.747688	0.508346	9.516846	-10.74511	19.47203	-8.50942	30.46232	-86.45024
21-Nov	15:11:14	127634.625	-0.342183	0.507453	41.569542	-8.811885	38.14141	-25.1845	30.45995	-86.47228
22-Nov	17:09:35	2493.819824	-0.056356	0.507255	-6.543202	-11.574341	-19	-6.5432	30.46231	-86.45440
22-Nov	21:14:05	5106.95166	-0.980048	0.506517	12.308069	-19.642508	19.81228	-10.9527	30.45623	-86.46824
22-Nov	19:47:36	214.719147	-0.972443	0.506185	0.138572	-10.264839	18.99326	0.524603	30.45728	-86.45575
21-Nov	17:24:34	6449.285156	-0.677496	0.505285	-6.60974	-25.479662	-19.6639	-4.24495	30.44773	-86.47148
22-Nov	22:42:41	49966.19922	-0.123497	0.505059	9.582494	-33.466717	-19.1643	9.249439	30.45272	-86.45590
22-Nov	21:16:27	40523.14063	-0.095803	0.504939	-31.737944	-8.210234	25.65252	26.65043	30.45625	-86.47255
21-Nov	19:18:17	810.200623	-0.13057	0.504657	0.300934	-15.865782	18.97792	-0.96384	30.44420	-86.47359
24-Nov	19:47:16	42849.48047	-0.605931	0.502869	41.636002	-14.011886	-40.9475	-20.4415	30.45446	-86.47471
22-Nov	18:46:27	42975.52344	-0.968753	0.502626	0.920103	-11.701714	15.81229	-10.5744	30.45857	-86.47443
21-Nov	21:09:04	31726.98242	-0.535424	0.500107	8.104445	-10.359603	19.27127	-7.43642	30.46657	-86.45730
22-Nov	21:41:33	336.853424	-0.871927	0.498898	-0.293568	-13.917155	18.99867	-0.3697	30.45554	-86.45014
21-Nov	20:38:44	51584.77344	-0.643722	0.493652	-21.961277	-17.503906	19.75486	21.28481	30.46720	-86.46668
22-Nov	21:11:50	479.027832	-0.09731	0.489599	-5.531765	-12.746639	18.90056	5.862518	30.45619	-86.46419
22-Nov	19:19:45	686.087158	-0.98063	0.489466	6.671268	-11.947003	19.32311	-5.66774	30.45791	-86.47024
21-Nov	15:22:50	71884.04688	-0.987655	0.488435	42.038139	-17.786276	-21.8861	40.61036	30.44962	-86.46658
23-Nov	0:15:00	1157.106323	-0.515802	0.487708	3.675105	-10.831646	17.94967	-7.23295	30.46298	-86.45462

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
22-Nov	17:35:55	22417.45313	-0.795017	0.484753	-6.570197	-15.837168	-17.9007	-9.15055	30.46116	-86.47067
21-Nov	17:08:46	11179.94141	0.426439	0.484328	24.477442	-16.977991	20.66118	-23.0924	30.45003	-86.45261
22-Nov	21:17:19	9619.792969	-0.791679	0.483342	-19.368383	-9.175056	20.61577	17.63872	30.45665	-86.47409
22-Nov	22:30:18	16500.01367	-0.964995	0.480959	-36.626484	-18.943201	19.63633	36.28931	30.45048	-86.47248
24-Nov	16:49:34	1043.398437	-0.748285	0.479099	-10.832631	-12.110383	-19.3665	-10.1629	30.46221	-86.45614
22-Nov	20:34:24	548.78656	-0.777158	0.478211	0.349819	-10.263147	18.27207	5.220529	30.45662	-86.47558
24-Nov	16:26:28	7034.647461	0.545117	0.477408	-1.250345	32.639721	-19.0409	0.078074	30.46255	-86.46429
21-Nov	21:58:56	1697.824829	-0.597716	0.474494	19.121826	-9.405453	-19.9747	18.10124	30.46771	-86.46084
21-Nov	20:40:57	744.380188	-0.455153	0.470738	-7.062256	-12.526017	17.9977	9.325133	30.46714	-86.47090
21-Nov	15:37:52	21127.06836	-0.780157	0.469777	20.796061	-30.482389	18.63416	-21.1245	30.45114	-86.44573
24-Nov	20:06:54	431.897522	-0.130584	0.469393	-8.317849	-9.736111	-18.5386	-9.30083	30.46232	-86.45699
22-Nov	22:00:14	22203.74219	-0.802393	0.468237	-10.213881	-11.599079	-18.8188	-10.5439	30.45317	-86.46488
24-Nov	16:48:09	1641.862671	-0.944523	0.467082	17.132082	-15.798629	-19.8706	16.11422	30.46187	-86.45848
22-Nov	20:28:57	647.505981	-0.763779	0.46633	2.803813	-11.816385	19.04604	-2.47179	30.45679	-86.46519
22-Nov	21:34:16	76014.88281	-0.5774	0.463625	5.499893	-13.724823	-19	5.499893	30.45380	-86.44533
22-Nov	21:44:41	746.345459	-0.605972	0.463139	-0.342336	-14.349405	18.97648	1.005218	30.45557	-86.45624
24-Nov	19:51:24	1308654.75	-0.72755	0.459708	48.71973	0.233684	-41.9304	31.24821	30.46126	-86.47382
21-Nov	16:33:16	13747.46973	-0.767747	0.455909	29.939764	-10.078954	-20.0333	29.25844	30.44836	-86.46421
22-Nov	17:19:09	385.830475	-0.830084	0.455871	4.87908	-8.629469	19.40592	-2.86631	30.46233	-86.45079
22-Nov	18:15:18	446.746368	0.561624	0.454606	3.713646	-12.115786	-19.3319	1.033216	30.46084	-86.46608
22-Nov	23:24:08	1944.709839	-0.978266	0.453747	14.80986	-9.851927	-19	14.80986	30.46261	-86.45525
21-Nov	14:56:59	57.859886	-0.607421	0.453746	-1.948623	-4.776654	-1.94862	19	30.46874	-86.47584
22-Nov	23:57:39	7638.951172	-0.152925	0.453354	17.495165	-6.789049	-18.6918	17.8241	30.46254	-86.46242
22-Nov	22:36:14	1845.939575	0.364417	0.452626	-18.525118	-11.038618	-17.6615	-19.8054	30.45262	-86.46803
22-Nov	17:31:28	843.712463	-0.292154	0.450464	2.063996	-12.133309	16.58451	9.498112	30.46637	-86.47190
22-Nov	19:20:11	2824.554443	-0.682652	0.448224	17.622715	-9.233369	18.68955	-17.9516	30.45786	-86.47108
21-Nov	17:53:43	594.918518	-0.663734	0.446698	-6.058616	-13.680826	19.19987	5.391835	30.44546	-86.46483
22-Nov	19:19:20	9713.141602	-0.805591	0.445175	-17.50975	-12.386522	19	17.50975	30.45801	-86.46944
22-Nov	17:31:02	2459.912598	-0.287573	0.443687	1.328576	-14.505548	18.21415	5.568658	30.46670	-86.47111
22-Nov	17:13:39	140286.4219	-0.762342	0.441379	22.91622	-37.359802	-29.7362	-1.38275	30.46304	-86.44700
21-Nov	21:06:04	26660.25	-0.030775	0.441061	31.189236	-8.411166	19.54143	-30.8529	30.46644	-86.45143
23-Nov	0:03:22	48018.94531	-0.940231	0.439536	-26.973541	-8.70663	-19	-26.9735	30.46243	-86.45105
21-Nov	20:48:58	1889.7146	0.14321	0.439527	-12.299293	-16.744232	-17.8557	-13.9084	30.46876	-86.46338
21-Nov	22:10:16	128820.0703	-0.417096	0.438038	-4.898601	-37.538338	19	4.898601	30.46527	-86.44395
22-Nov	21:59:39	2151.60791	-0.040048	0.437842	14.509277	-11.093736	-19	14.50928	30.45327	-86.46598

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
24-Nov	16:31:12	3.656599	0.94875	0.43751	3.148561	3.051639	-19.0521	2.816486	30.46255	-86.45551
21-Nov	20:35:46	773.835144	0.270195	0.436845	4.606488	-10.581223	19	-4.60649	30.46707	-86.46100
21-Nov	14:55:12	435.357147	-0.018022	0.43622	-3.783351	-6.735374	5.902389	18.45198	30.47160	-86.47522
22-Nov	22:41:00	9274.412109	-0.836098	0.435082	-19.865892	-23.00983	-19.6817	-19.1907	30.45262	-86.45905
21-Nov	17:33:56	1276.326782	-0.037637	0.434688	5.486616	-15.176691	-19.3364	4.147878	30.44780	-86.45383
22-Nov	18:45:01	100133.5625	-0.333283	0.434424	-39.122845	-15.931924	17.62306	39.7621	30.45859	-86.47186
21-Nov	15:54:33	4069.240479	-0.801063	0.43357	-2.419128	-21.427059	-19.1125	1.250689	30.44886	-86.47212
21-Nov	20:16:21	700.185242	-0.745641	0.433282	5.000283	-10.94875	-19.3025	3.66273	30.46941	-86.45964
21-Nov	15:28:54	1015.908691	-0.964301	0.432756	-6.886172	-14.555031	-18.7481	-7.54507	30.44951	-86.45448
24-Nov	20:03:59	6727.825684	-0.499966	0.431406	-19.419012	-15.654745	-19.6661	-18.7441	30.46228	-86.46277
22-Nov	22:18:28	178.836716	-0.563331	0.430472	1.574599	-10.738642	18.96963	-1.90595	30.45035	-86.44920
21-Nov	20:49:45	341.30072	0.519042	0.430368	5.184422	-13.566841	-19.0876	4.852037	30.46888	-86.46191
22-Nov	22:38:08	973.024841	-0.275333	0.427727	-9.825292	-11.223049	-18.2683	-11.1267	30.45261	-86.46452
22-Nov	17:19:50	229020.0469	-0.701801	0.427551	-48.274448	-10.357863	14.7203	49.74671	30.46248	-86.45208
22-Nov	20:04:47	1057.658325	-0.822902	0.426749	-7.281757	-12.576604	-19.1242	-6.94905	30.45492	-86.46189
24-Nov	16:33:05	39712.0625	-0.935767	0.426556	-29.388657	-9.42247	-19.51	-29.0526	30.46245	-86.45204
22-Nov	22:01:26	4609.510254	-0.87349	0.425965	16.363735	0.378594	-20.0952	14.9985	30.45321	-86.46264
22-Nov	18:50:15	4069.708008	0.526086	0.425961	9.645219	-13.729723	-20.0338	7.257807	30.46015	-86.46951
22-Nov	21:28:44	2003.923706	0.458436	0.425736	14.763023	-12.756357	-19.9835	13.40169	30.45377	-86.45633
19-Nov	19:28:56	103658.2656	0.350797	0.42572	12.686938	14.113877	-19.6379	11.67517	30.46976	-86.46144
21-Nov	21:16:30	2395.942627	-0.306975	0.424777	12.849082	-11.123243	17.02685	-15.3683	30.46649	-86.47190
22-Nov	21:59:56	707.472839	0.476715	0.42387	2.034751	-13.583911	-18.9174	2.696602	30.45321	-86.46545
21-Nov	21:25:06	740225.75	-0.700941	0.423417	-14.197281	-60.156506	-18.7493	-14.5267	30.46823	-86.46028
21-Nov	19:55:17	1019.716553	-0.801633	0.422943	-3.925999	-18.642752	18.85141	4.586698	30.44368	-86.47166
21-Nov	16:07:19	177792.0781	-0.149317	0.422858	23.435352	-48.212795	-18.1705	24.08417	30.44896	-86.44712
23-Nov	0:01:17	3697.751953	-0.764813	0.421913	15.524611	-12.451349	-17.5746	17.12149	30.46263	-86.45518
21-Nov	19:04:44	121143.1719	-0.810193	0.417518	-13.608563	-42.902821	18.7596	13.93809	30.44439	-86.44680
24-Nov	19:50:17	1485516.875	-0.087667	0.411497	-29.83252	-9.759386	28.43448	-21.0347	30.45953	-86.47440
24-Nov	20:09:22	40333.88672	0.008374	0.411224	35.419338	0.50179	-19	35.41934	30.46244	-86.45211
22-Nov	18:45:49	3890.506836	-0.554319	0.411113	11.471614	-9.266477	19.75394	-10.1183	30.45843	-86.47332
22-Nov	19:26:55	10935.66016	-0.457507	0.410785	-16.664646	-20.639803	-19	-16.6646	30.45955	-86.46539
22-Nov	20:42:50	366.785736	-0.281391	0.410347	1.338065	-9.901514	-19.0443	-0.32299	30.45436	-86.46213
22-Nov	17:34:23	19370.55469	-0.871454	0.410327	9.289514	-19.416103	-6.16405	20.23115	30.46211	-86.47340
22-Nov	23:48:21	9855.4375	0.149571	0.409787	-24.661839	-11.641703	19	24.66184	30.46416	-86.47004
21-Nov	20:47:31	2699.285645	-0.737879	0.409322	-1.81417	-14.841532	-18.5626	-4.4408	30.46881	-86.46611

TABLE E-2. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Long
21-Nov	22:14:03	22918.00977	-0.45455	0.407058	-32.868092	-11.203276	21.24648	31.46265	30.46551	-86.45133
19-Nov	19:28:28	483.587677	0.122691	0.406564	0.066	-8.597285	-18.9491	1.391212	30.46974	-86.46233
21-Nov	18:51:42	1733.108154	-0.540426	0.405189	11.998123	-14.933217	-19.7907	10.64352	30.44658	-86.45863
22-Nov	21:12:35	108258.2656	-0.655872	0.404923	-55.559361	-16.931017	16.06621	56.4776	30.45632	-86.46557
24-Nov	20:18:36	61111.11328	-0.870928	0.403483	-37.928013	-9.595173	18.33517	38.25383	30.46243	-86.45204
19-Nov	19:22:51	192.501526	-0.026524	0.4021	2.729506	-0.009999	6.933619	17.89903	30.47154	-86.47169
21-Nov	19:20:53	146705.5	0.380533	0.401541	-0.766015	26.814295	-17.4129	7.640562	30.44595	-86.47456
23-Nov	20:17:54	50539.72266	-0.875259	2.937257	-1.390355	-17.846657	14.97424	11.77732	30.47092	-86.46930
23-Nov	20:13:58	64191.125	-0.437365	1.914211	-1.476217	-21.943016	-18.7347	3.491646	30.47289	-86.47060
23-Nov	20:13:56	13465.21484	-0.85274	0.996877	11.848776	-16.973288	-15.8476	15.81916	30.47293	-86.47065
23-Nov	20:19:53	14664.4834	0.511883	0.708994	-19.343765	-15.121118	3.532706	26.8831	30.46931	-86.47219
23-Nov	20:20:37	22211.33984	-0.760975	0.598553	9.518229	-15.377518	19.19803	9.112197	30.46861	-86.47311

SELECTED MAGNETIC TARGETS

Table E-3 lists the sensor target results from the Choctawhatchee Bay tests after additional processing beyond Table E-2. Targets in E-3 include only targets with moment between 1×10^4 and 1×10^5 γ-ft^3 and cosine $\theta < -0.2$. Targets with positive cosine θ are struck through. The data columns are the same as for Table E-2. Targets in Table E-3 are listed in order of decreasing magnetic moment magnitude.

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
11/21	21:47:41	93966.31250	-0.872879	7.56544	7.539513	-17.389521	19	-7.53951	30.46586	-86.46615
11/22	23:45:43	93846.28125	-0.591923	2.332167	17.763317	-15.916918	19.90362	-16.7446	30.46410	-86.46475
11/21	19:45:15	90530.18750	-0.969221	1.485056	-35.863823	-25.439362	19	35.86382	30.44382	-86.45284
~~11/22~~	~~22:27:52~~	~~89885.46875~~	~~0.079131~~	0.692467	-61.177368	-12.326142	21.12349	60.47701	30.45051	-86.46780
11/22	18:17:15	89690.91406	-0.282548	1.876571	33.174015	-11.613286	-17.2378	34.12293	30.46079	-86.46220
~~11/24~~	~~16:35:50~~	~~84138.96875~~	~~-0.722104~~	~~0.617734~~	~~-1.22948~~	~~-46.964001~~	~~-10.1732~~	~~-16.094~~	~~30.46364~~	~~-86.44744~~
11/21	17:13:21	83678.05469	-0.725986	0.57425	-23.164963	-36.726456	18.59282	23.49303	30.45018	-86.46129
11/22	21:58:18	77755.60938	-0.8499	1.061372	30.834326	-15.510209	-20.5877	29.79769	30.45326	-86.46854
~~11/24~~	~~16:42:35~~	~~76745.78906~~	~~0.500232~~	~~2.696699~~	~~32.021576~~	~~9.692636~~	~~19~~	~~-32.0216~~	~~30.46225~~	~~-86.45209~~
11/22	21:34:16	76014.88281	-0.5774	0.463625	5.499893	-13.724823	-19	5.499893	30.45380	-86.44533
11/21	15:22:50	71884.04688	-0.987655	0.488435	42.038139	-17.786276	-21.8861	40.61036	30.44962	-86.46658
~~11/19~~	~~19:29:06~~	~~70998.00000~~	~~0.128119~~	0.704278	20.911385	-11.443491	-21.0818	18.81079	30.46979	-86.46113
11/21	16:23:32	69661.08594	-0.515398	0.659613	8.804375	-16.088516	18.84345	-9.13463	30.45056	-86.46725
11/21	21:13:45	66374.83594	-0.952652	6.123984	-6.487507	-16.841887	18.63443	7.472999	30.46660	-86.46651
11/22	17:36:25	63853.05469	-0.856927	0.556462	-4.81951	-24.228708	-17.8744	-8.04561	30.46126	-86.46969
11/21	20:12:36	62711.87891	-0.9938	4.195496	-8.950202	-19.760464	-18.1476	-10.5721	30.46933	-86.46675
11/24	16:29:55	61847.08984	0.941437	0.670698	-28.075729	-24.046082	-19	-28.0757	30.46243	-86.45789
11/24	20:18:36	61111.11328	-0.870928	0.403483	-37.928013	-9.595173	18.33517	38.25383	30.46243	-86.45204
11/24	16:35:39	60177.51172	-0.153989	1.402814	20.394487	-10.771965	-27.8736	0.013286	30.46346	-86.44772
~~11/22~~	~~23:18:11~~	~~56778.51953~~	~~0.201976~~	4.343009	-15.423434	-12.870183	-17.8778	-16.7112	30.46260	-86.46738
~~11/21~~	~~20:46:19~~	~~56173.75000~~	~~0.058482~~	1.703697	32.181942	-16.228369	-23.294	29.22446	30.46873	-86.46832

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
11/22	21:42:53	55676.91406	-0.434778	0.623213	-37.113716	-11.540784	20.28368	36.42802	30.45566	-86.45282
11/24	20:28:42	55506.38281	-0.912256	0.747593	-22.965771	-9.404303	-18.5963	-23.2939	30.46244	-86.45203
11/22	23:07:33	53469.13281	-0.91735	1.31798	-18.556154	-19.080935	17.65931	19.83633	30.46373	-86.46461
11/21	20:38:44	51584.77344	-0.643722	0.493652	-21.961277	-17.503906	19.75486	21.28481	30.46720	-86.46668
11/22	22:42:41	49966.19922	-0.123497	0.505059	9.582494	-33.466717	-19.1643	9.249439	30.45272	-86.45590
11/23	0:03:22	48018.94531	-0.940231	0.439536	-26.973541	-8.70663	-19	-26.9735	30.46243	-86.45105
11/21	15:03:12	47590.80078	-0.865996	0.835763	7.465096	-23.606955	-20.4064	-0.55223	30.46656	-86.46567
~~11/22~~	~~21:55:58~~	~~47472.86719~~	~~0.377136~~	3.176042	-8.744171	-12.726071	-20.8717	-1.3544	30.45354	-86.47310
11/21	20:12:32	46009.82422	-0.981876	1.162566	12.99714	-17.561483	-20.0605	11.29172	30.46938	-86.46689
11/21	16:01:05	45423.69531	-0.848767	1.009171	11.090372	-30.937891	-18.6014	11.74671	30.44893	-86.45937
~~11/22~~	~~19:08:20~~	~~44861.88281~~	~~-0.346586~~	~~0.654287~~	~~-20.122416~~	~~-3.698889~~	~~19.69069~~	~~19.44707~~	~~30.45795~~	~~-86.44761~~
11/22	21:17:03	44320.60938	-0.414744	0.749038	-14.229917	-12.737745	22.72108	6.873365	30.45651	-86.47362
11/24	16:52:25	43589.72266	-0.244312	1.524994	-16.749174	-9.385858	-20.1221	-15.383	30.46223	-86.45092
11/22	18:46:27	42975.52344	-0.968753	0.502626	0.920103	-11.701714	15.81229	-10.5744	30.45857	-86.47443
11/24	19:47:16	42849.48047	-0.605931	0.502869	41.636002	-14.011886	-40.9475	-20.4415	30.45446	-86.47471
11/22	17:11:24	41922.76172	-0.20473	3.323554	-11.410423	-11.741365	-19.9222	-9.71104	30.46224	-86.45095
11/22	22:03:14	40705.81250	-0.546997	3.575266	-13.102695	-16.227013	-19	-13.1027	30.45316	-86.45931
11/22	21:16:27	40523.14063	-0.095803	0.504939	-31.737944	-8.210234	25.65252	26.65043	30.45625	-86.47255
~~11/24~~	~~20:09:22~~	~~40333.88672~~	~~0.008374~~	~~0.411224~~	~~35.419338~~	~~0.50179~~	~~-19~~	~~35.41934~~	~~30.46244~~	~~-86.45211~~
11/22	21:57:07	39771.13281	-0.73362	3.788634	-3.695401	-16.178194	-19.2498	-2.02538	30.45323	-86.47078
11/24	16:33:05	39712.06250	-0.935767	0.426556	-29.388657	-9.42247	-19.51	-29.0526	30.46245	-86.45204
11/22	22:52:35	39200.33203	-0.65097	0.63707	19.483961	-23.105625	-23.2587	-14.1301	30.45806	-86.44064
~~11/22~~	~~22:28:33~~	~~38481.37500~~	~~0.275406~~	1.101552	-28.935236	-14.650803	20.48831	27.9012	30.45041	-86.46913
11/22	23:17:36	37720.30859	-0.804672	0.537006	16.233778	-12.630619	-21.5303	12.68784	30.46254	-86.46857
11/21	21:16:11	37400.44922	-0.920866	0.833695	23.486023	-9.288162	19	-23.486	30.46643	-86.47127
~~11/21~~	~~20:37:20~~	~~37015.73828~~	~~0.291541~~	11.759234	-8.596257	-12.95016	19.28843	7.92793	30.46711	-86.46400
~~11/22~~	~~17:03:33~~	~~36160.23828~~	~~0.19545~~	1.27474	-7.756194	-14.620687	-15.2014	-13.7868	30.46075	-86.46560
11/24	20:09:58	36080.91406	-0.300953	0.738456	-31.428202	-10.194255	-22.1811	-29.27	30.46222	-86.45093
11/22	20:20:08	36068.36719	-0.259591	1.021163	8.920712	-12.009211	17.96345	-10.8579	30.45672	-86.44878
11/24	20:25:12	35421.21094	-0.277526	2.383821	-19.69878	-11.286084	-9.79267	-25.5567	30.46239	-86.45840
11/22	20:41:46	34881.14063	-0.470368	1.00017	5.204595	-16.793993	-19.5803	2.168263	30.45429	-86.46424

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
~~11/21~~	~~22:11:02~~	~~33948.30078~~	~~0.326022~~	4.137178	-6.321825	-17.297707	19	6.321825	30.46542	-86.44543
11/24	20:10:53	33064.55469	-0.449817	2.116439	-6.629931	-10.181569	-19.3209	-5.62646	30.46221	-86.44910
11/21	17:49:47	32778.06250	-0.604199	0.616359	28.647795	-14.645571	17.98863	-29.2934	30.44550	-86.45706
11/24	16:27:35	32308.90625	-0.462305	1.626312	4.811862	-17.21167	-19.1564	4.14584	30.46259	-86.46222
11/21	15:27:34	32114.19922	-0.91105	3.614915	-1.034928	-17.530846	-18.9198	-2.02789	30.44954	-86.45711
11/19	19:26:50	31920.08398	-0.41962	1.788988	-2.798234	-12.458282	-18.8908	-3.45962	30.46971	-86.46550
11/21	21:57:07	31827.29102	-0.921813	0.748549	21.763128	-14.099904	-22.8035	17.73791	30.46771	-86.46431
11/21	21:09:04	31726.98242	-0.535424	0.500107	8.104445	-10.359603	19.27127	-7.43642	30.46657	-86.45730
11/22	17:27:37	31289.92188	-0.920906	1.117103	-3.90597	-16.217218	16.38077	-10.3888	30.46629	-86.46445
11/24	16:26:56	31207.47070	-0.65719	14.15526	6.362972	-15.902409	-19.4823	4.6828	30.46257	-86.46343
11/22	22:23:09	30832.53906	-0.216181	0.729526	-20.965525	-30.668304	19.36301	20.63074	30.45048	-86.45855
11/22	23:54:31	30553.07227	-0.933094	1.507218	14.327656	-13.229959	-22.4976	7.755088	30.46271	-86.46853
11/19	19:19:01	29158.81445	-0.927861	0.611689	6.260723	-17.498896	-19.7152	-3.39207	30.47024	-86.46878
11/22	20:00:01	28912.57422	-0.503663	0.997469	17.755827	-12.961334	-21.2862	14.93874	30.45489	-86.47137
11/22	21:17:14	28870.35352	-0.416088	2.911776	15.828013	-11.597805	13.54213	-20.6915	30.45652	-86.47396
~~11/22~~	~~19:27:57~~	~~28861.35156~~	~~0.044224~~	1.867516	8.468908	-11.998456	-19.6658	6.780722	30.45967	-86.46330
11/24	19:49:07	28669.06836	-0.840736	2.97859	-15.180535	-10.054584	14.84663	-19.262	30.45757	-86.47449
11/21	21:11:57	28533.27930	-0.304993	0.861511	-5.974603	-12.871233	19.10138	5.642097	30.46655	-86.46297
11/24	16:29:33	28339.02930	-0.292817	2.882034	-15.844596	-13.289184	-19	-15.8446	30.46247	-86.45857
11/22	21:49:12	28166.79102	-0.833701	0.96682	-13.997291	-20.176226	18.75282	14.32675	30.45566	-86.46468
11/22	21:29:30	27399.38086	-0.39435	1.763741	23.309109	-10.753144	-17.3278	24.5777	30.45383	-86.45481
11/22	18:47:59	27294.38086	-0.952635	0.606945	-5.726619	-12.426085	-16.3005	-11.3177	30.46035	-86.47379
11/21	21:22:36	27290.40039	-0.810296	2.056948	2.564481	-16.704016	-19.1512	0.898763	30.46821	-86.46504
11/21	20:14:48	26827.80273	-0.230571	1.960912	17.802891	-12.664342	-19.3078	17.46858	30.46945	-86.46256
11/22	21:25:41	26815.94727	-0.528114	3.466559	-12.312263	-12.502294	-18.5587	-12.9679	30.45371	-86.46197
11/21	21:48:37	26755.19336	-0.421311	10.975259	-1.028917	-13.704809	18.92011	2.02189	30.46597	-86.46798
11/21	21:06:04	26660.25000	-0.030775	0.441061	31.189236	-8.411166	19.54143	-30.8529	30.46644	-86.45143
11/22	21:59:21	25890.34570	-0.272397	3.005488	-17.321596	-12.310684	-18.3839	-17.9741	30.45318	-86.46655
~~11/22~~	~~17:42:10~~	~~25829.62109~~	~~0.207~~	4.874785	-15.975845	-9.781433	-17.8393	-17.2623	30.46123	-86.45890
~~11/19~~	~~19:31:20~~	~~25318.49414~~	~~-0.094708~~	~~1.61531~~	~~-1.78591~~	~~-0.984118~~	~~-19.0674~~	~~-0.78908~~	~~30.46969~~	~~-86.45685~~
11/22	21:58:11	24880.33203	-0.882343	0.938558	-20.464117	-16.243353	-20.3812	-19.0889	30.45312	-86.46876
11/22	17:07:29	24584.14648	-0.268215	7.308131	-4.57179	-11.027304	-18.9173	-4.90269	30.46236	-86.45844

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
11/21	21:28:07	23605.24609	-0.610791	3.758584	9.02074	-12.859466	-19.3032	8.352154	30.46829	-86.45452
~~11/21~~	~~17:20:20~~	~~23133.59570~~	~~0.312501~~	1.12492	-7.248725	-21.734362	19.45936	5.905694	30.45052	-86.47455
11/24	20:06:11	22969.62695	-0.230872	2.957125	17.190737	-10.356402	-19.8737	16.17279	30.46236	-86.45842
11/21	22:14:03	22918.00977	-0.45455	0.407058	-32.868092	-11.203276	21.24648	31.46265	30.46551	-86.45133
11/21	21:57:11	22859.68750	-0.989484	2.223682	-9.80406	-16.022104	-16.5464	-13.5401	30.46764	-86.46416
11/22	20:02:42	22761.04688	-0.306757	0.528749	-23.514072	-21.19689	-18.5867	-23.8421	30.45481	-86.46602
11/22	17:35:55	22417.45313	-0.795017	0.484753	-6.570197	-15.837168	-17.9007	-9.15055	30.46116	-86.47067
11/22	22:00:14	22203.74219	-0.802393	0.468237	-10.213881	-11.599079	-18.8188	-10.5439	30.45317	-86.46488
~~11/22~~	~~18:33:10~~	~~22027.55664~~	~~0.214914~~	1.441151	21.558893	-10.718031	19.74082	-20.8827	30.45839	-86.44982
11/22	19:26:09	21936.01172	-0.735242	1.243527	-17.389961	-11.809291	-18.0638	-18.3605	30.45956	-86.46696
11/21	21:55:51	21580.27930	-0.143371	0.566661	-27.835135	-20.000624	-21.3537	-26.0733	30.46760	-86.46671
11/21	17:10:20	21284.95117	-0.996599	1.764426	-17.18755	-16.158451	18.07443	18.15838	30.45013	-86.45561
11/21	15:37:52	21127.06836	-0.780157	0.469777	20.796061	-30.482389	18.63416	-21.1245	30.45114	-86.44573
11/22	20:02:15	21021.37891	-0.242733	1.432519	-17.015291	-16.066956	-19	-17.0153	30.45479	-86.46691
~~11/22~~	~~20:43:41~~	~~20780.33789~~	~~0.050943~~	2.396009	11.129927	-12.299569	-19.5565	10.12029	30.45447	-86.46046
11/21	22:18:42	20609.32617	-0.494028	3.833697	-9.39231	-9.608771	19.16102	9.059284	30.46539	-86.46042
11/22	19:56:48	20529.71484	-0.159223	0.521472	-23.811171	-9.187509	15.50122	26.22373	30.45736	-86.47300
11/22	18:45:02	20385.96875	-0.586113	4.610852	-10.18846	-11.285686	19.344	9.519163	30.45851	-86.47188
~~11/23~~	~~0:15:56~~	~~20329.43750~~	~~0.580018~~	1.311422	13.667149	-12.142284	10.35967	-20.9873	30.46353	-86.45622
11/22	20:32:14	19932.80078	-0.216092	3.648846	-9.553318	-11.756193	18.09507	11.17292	30.45673	-86.47144
11/22	17:34:23	19370.55469	-0.871454	0.410327	9.289514	-19.416103	-6.16405	20.23115	30.46211	-86.47340
~~11/22~~	~~17:34:23~~	~~19155.78906~~	~~0.169982~~	3.077853	-9.256021	-11.61294	-19.7274	7.583129	30.46207	-86.47345
11/21	21:01:56	18935.36719	-0.667481	3.421598	12.180752	-10.116215	18.33647	-13.1584	30.46633	-86.44354
11/21	18:27:21	18919.83789	-0.752517	0.868591	27.355272	-14.193446	20.40563	-26.3234	30.44489	-86.46437
11/24	16:23:38	18673.72852	-0.88325	0.669924	21.608274	-22.842991	3.344595	28.57851	30.46535	-86.46818
11/19	19:25:26	18617.14453	-0.847383	0.627244	4.109272	-18.067358	-19.1318	3.443678	30.46975	-86.46822
11/22	21:14:39	18597.94531	-0.500668	0.789413	-21.491377	-14.109015	18.62203	21.8197	30.45629	-86.46925
11/22	21:24:29	18402.30859	-0.965526	0.995886	9.498549	-14.911144	-19	9.498549	30.45377	-86.46422
11/22	21:13:33	18372.50391	-0.924056	0.772725	23.497013	-12.851907	17.31465	-24.7651	30.45614	-86.46730
11/21	22:21:21	18346.19141	-0.885035	1.971667	4.791184	-17.237728	19.28793	-3.45414	30.46539	-86.46565
11/22	23:45:48	18326.83789	-0.871549	3.38267	4.157583	-16.051783	19	-4.15758	30.46414	-86.46492
11/22	17:32:09	17816.71484	-0.790909	1.150991	14.454478	-15.652025	23.08785	6.073139	30.46552	-86.47289
11/22	23:20:35	17469.42969	-0.548236	1.385653	-18.175203	-11.568483	-18.6799	-18.504	30.46249	-86.46246

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
~~11/23~~	~~0:10:32~~	~~17146.10352~~	~~0.132084~~	1.054558	-17.982098	-17.379908	21.04984	15.53254	30.46272	-86.44627
11/21	18:56:42	17107.93945	-0.754115	3.406495	-11.24064	-19.930584	-18.3857	-12.2196	30.44662	-86.44904
11/22	23:12:07	16933.13867	-0.350002	0.613261	5.036656	-16.124807	11.03514	-16.2663	30.46397	-86.47308
11/22	16:29:30	16634.23438	-0.709435	0.609206	28.826302	-15.996149	-18.494	29.15351	30.46260	-86.45866
11/22	17:18:18	16589.85352	-0.54371	5.254983	-4.86033	-10.247757	19.15805	4.194279	30.46234	-86.44921
11/21	20:29:27	16579.50977	-0.254019	2.943145	12.28353	-14.157838	19	-12.2835	30.46705	-86.44900
~~11/22~~	~~20:25:27~~	~~16513.63867~~	~~0.2838~~	~~6.472543~~	~~-10.593627~~	~~-11.703802~~	~~18.81222~~	~~10.92361~~	~~30.45677~~	~~-86.45870~~
11/22	22:30:18	16500.01367	-0.964995	0.480959	-36.626484	-18.943201	19.63633	36.28931	30.45048	-86.47248
11/22	19:25:21	16235.39844	-0.572821	0.776168	21.143627	-9.188704	-19.3661	20.80881	30.45965	-86.46859
11/22	18:55:48	16222.14941	-0.469459	10.503093	-2.219067	-10.964843	-19.0358	-1.88713	30.46011	-86.45873
11/22	17:12:19	16124.72266	-0.505452	2.189914	6.642094	-12.440958	-19	6.642094	30.46234	-86.44920
~~11/22~~	~~18:54:56~~	~~15726.70117~~	~~0.170486~~	~~2.182924~~	~~-11.765416~~	~~-13.537157~~	~~-19.5897~~	~~-10.7549~~	~~30.46019~~	~~-86.46040~~
11/21	15:49:02	15695.58594	-0.752945	1.245052	-7.486735	-17.397827	18.86644	7.81719	30.45128	-86.46904
11/22	19:07:09	15678.37109	-0.735133	2.534276	8.026433	-13.284175	18.39382	-9.33225	30.45788	-86.44526
11/24	16:41:05	15529.49902	-0.517231	9.336432	8.429298	-9.383825	18.53281	-9.41213	30.46234	-86.44920
11/21	21:47:11	15390.76758	-0.844038	2.573352	3.205806	-16.147736	19.17734	-1.87262	30.46593	-86.46517
11/21	21:52:24	15366.11719	-0.503757	1.197872	3.165498	-14.529167	-19.0483	-2.86076	30.46752	-86.47322
11/22	19:24:39	15325.46387	-0.451729	2.000798	-6.244543	-9.964928	-19.1061	-5.912	30.45960	-86.47003
11/21	16:05:04	15311.25098	-0.394283	2.806095	2.495733	-13.732089	-19.1452	0.830277	30.44894	-86.45157
~~11/24~~	~~20:06:15~~	~~15277.42676~~	~~0.007391~~	~~0.567761~~	~~-23.63253~~	~~-11.360174~~	~~-19~~	~~-23.6325~~	~~30.46225~~	~~-86.45828~~
11/24	20:17:06	15209.47656	-0.488831	3.446592	11.569971	-9.243472	19.57949	-10.5597	30.46233	-86.44920
11/21	17:47:53	14949.45898	-0.728905	1.617789	19.19129	-16.967356	19.33204	-18.8568	30.44546	-86.45331
11/21	20:03:05	14387.99023	-0.00203	0.829315	-3.832596	-10.453901	-1.21556	-19.3445	30.45587	-86.47214
~~11/21~~	~~16:13:51~~	~~14217.80273~~	~~0.300661~~	~~1.174546~~	~~24.82547~~	~~-13.197995~~	~~16.30095~~	~~-26.6755~~	~~30.45064~~	~~-86.44765~~
11/21	20:38:04	14114.26270	-0.873063	1.012418	-20.512072	-14.391833	17.90044	21.47834	30.46712	-86.46541
~~11/22~~	~~17:44:04~~	~~13786.53027~~	~~0.492601~~	~~1.809152~~	~~-14.557593~~	~~-11.288615~~	~~-20.1965~~	~~-12.8462~~	~~30.46125~~	~~-86.45550~~
11/21	16:33:16	13747.46973	-0.767747	0.455909	29.939764	-10.078954	-20.0333	29.25844	30.44836	-86.46421
11/21	16:34:21	13590.01172	-0.831883	1.10383	-10.593464	-21.334822	-18.0044	-12.2091	30.44824	-86.46205
11/22	18:56:17	13556.98340	-0.204442	1.189553	4.6	-11.371376	-19	4.6	30.46009	-86.45780
11/22	19:19:25	13379.65039	-0.625403	3.322944	2.851358	-9.96737	18.82473	-3.84183	30.45794	-86.46960
~~11/24~~	~~19:44:30~~	~~13374.69238~~	~~0.317407~~	~~1.192911~~	~~-11.886391~~	~~-19.173784~~	~~22.38164~~	~~-1.16119~~	~~30.45111~~	~~-86.47171~~
~~11/21~~	~~21:34:05~~	~~13176.52148~~	~~0.115604~~	~~0.514071~~	~~-11.766134~~	~~-23.138447~~	~~-22.3375~~	~~-0.68977~~	~~30.46798~~	~~-86.44300~~
11/22	22:01:24	13153.36231	-0.599151	5.372072	-1.269283	-12.164659	-18.9441	-1.9316	30.45316	-86.46270

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
11/21	19:12:31	13149.27344	-0.26072	0.754827	-19.729708	-19.181826	19.67698	19.0546	30.44437	-86.46230
~~11/22~~	~~23:58:17~~	~~13036.01758~~	~~0.211253~~	~~1.341026~~	~~10.94229~~	~~-12.280523~~	-18.6065	11.59871	30.46247	-86.46117
~~11/21~~	~~17:13:52~~	~~12929.26856~~	~~0.312013~~	~~0.621674~~	~~-20.837051~~	~~-15.376589~~	19.71563	20.16127	30.45012	-86.46226
~~11/22~~	~~17:37:27~~	~~12913.47168~~	~~0.134235~~	~~0.635871~~	~~22.691551~~	~~-11.134415~~	-20.9054	20.94924	30.46137	-86.46767
11/22	20:23:53	12860.97461	-0.556093	5.81883	-2.960818	-11.703973	18.94543	3.291963	30.45684	-86.45578
11/22	19:53:08	12713.55176	-0.550262	0.791669	3.788502	-22.638115	18.85621	-4.44928	30.45729	-86.46621
11/21	15:47:20	12617.69336	-0.753669	1.525118	14.358322	-13.967153	18.48733	-15.0127	30.45118	-86.46564
11/22	23:41:58	12523.24902	-0.955134	2.401611	-12.429779	-8.384764	19.21404	12.09629	30.46438	-86.45763
11/22	23:21:10	12517.07422	-0.422615	2.118963	9.377291	-11.338538	-18.4832	10.35882	30.46255	-86.46128
11/21	18:53:39	12449.72852	-0.276784	1.354266	3.169676	-15.487868	-18.8778	3.830836	30.44663	-86.45490
11/21	21:03:00	12314.31055	-0.03361	0.793344	-2.164229	-14.125281	19.1163	-0.50112	30.46630	-86.44554
11/22	22:19:25	12279.99707	-0.968144	0.70587	12.701231	-23.553371	19.43169	-12.0304	30.45037	-86.45109
11/21	21:47:38	12275.18066	-0.897385	1.919333	9.019032	-15.115163	18.8397	-9.34925	30.46586	-86.46605
11/24	16:26:56	12251.95606	-0.319165	1.041748	17.14982	-12.588484	-20.4224	15.4286	30.46260	-86.46343
11/24	16:27:37	12231.66406	-0.550762	0.763696	-2.948709	-16.720486	-19.0486	-2.61666	30.46257	-86.46216
11/21	14:54:12	12125.27441	-0.066154	1.299484	7.06533	-10.028943	16.06021	12.36886	30.47296	-86.47419
~~11/21~~	~~18:52:02~~	~~11903.10254~~	~~0.081961~~	~~3.228261~~	~~-11.174788~~	~~-17.10145~~	~~-18.8021~~	~~-11.5047~~	~~30.44656~~	~~-86.45799~~
11/21	20:38:40	11889.01563	-0.695652	0.913699	-10.751541	-12.378793	19.70371	9.399978	30.46716	-86.46655
11/22	18:48:16	11745.04297	-0.707553	0.880738	-8.993291	-10.713215	-20.7429	-3.4078	30.46036	-86.47330
~~11/22~~	~~22:31:40~~	~~11603.05469~~	~~0.476036~~	~~1.151649~~	~~9.736127~~	~~-14.288466~~	~~5.837416~~	~~-20.5357~~	~~30.45074~~	~~-86.47491~~
~~11/24~~	~~16:27:37~~	~~11531.09766~~	~~0.345727~~	~~0.943978~~	~~-7.971914~~	~~-13.93522~~	~~-19.1362~~	~~-7.6391~~	~~30.46256~~	~~-86.46216~~
11/21	21:57:10	11404.03223	-0.350474	2.129326	5.854508	-13.855014	-19.728	2.466249	30.46768	-86.46420
11/21	16:25:52	11379.60156	-0.991957	2.092567	8.445477	-14.268987	19.88762	-6.06701	30.45052	-86.47195
11/22	21:15:17	11355.01758	-0.703481	0.55286	-22.334549	-15.212234	19	22.33455	30.45634	-86.47040
11/21	21:13:09	11198.27832	-0.947577	0.639111	-3.255148	-16.266317	19.18078	1.921846	30.46662	-86.46534
~~11/21~~	~~17:08:46~~	~~11179.94141~~	~~0.426439~~	~~0.484328~~	~~24.477442~~	~~-16.977991~~	~~20.66118~~	~~-23.0924~~	~~30.45003~~	~~-86.45261~~
11/22	18:45:21	10969.84961	-0.716128	6.28671	-6.798039	-10.318835	19	6.798039	30.45850	-86.47245
11/22	19:26:55	10935.66016	-0.457507	0.410785	-16.664646	-20.639803	-19	-16.6646	30.45955	-86.46539
11/22	23:20:34	10894.32910	-0.875542	1.777222	-7.990226	-13.157406	-19	-7.99023	30.46252	-86.46250
11/21	17:07:51	10839.90723	-0.698756	1.258293	-19.999496	-16.360746	17.92727	20.96647	30.45019	-86.45086
11/21	15:48:00	10731.24121	-0.0207	2.555083	-6.623776	-13.228711	18.88151	6.954363	30.45126	-86.46697
~~11/21~~	~~20:57:53~~	~~10684.02441~~	~~0.390302~~	~~1.189784~~	~~-12.757546~~	~~-15.081651~~	~~-20.2294~~	~~-10.7016~~	~~30.46874~~	~~-86.44644~~
11/22	18:48:22	10560.20117	-0.665967	0.763562	-10.467755	-10.014564	-21.3728	-3.71166	30.46031	-86.47313

TABLE E-3. SELECTED MAGNETIC TARGETS, CONFIDENCE LEVEL >0.4; 500-lb BOMB MOMENT MAGNITUDE AND DIRECTION, CONTINUED

Date	Time Zulu	Mag Moment	Cos Theta	Dipole Fit	Y in Feet	Z in Feet	Delta X	Delta Y	Target Lat	Target Lon
~~11/22~~	~~23:12:55~~	~~10441.00781~~	~~0.523242~~	~~1.72884~~	~~-8.908238~~	~~-13.428958~~	~~17.16445~~	~~12.07222~~	~~30.46453~~	~~-86.47432~~
11/22	23:12:32	10392.05273	-0.394871	2.163919	1.824118	-12.886556	16.61543	-9.39441	30.46440	-86.47362
11/22	17:56:03	10346.44141	-0.883047	7.121546	3.073705	-9.662384	19.16813	-1.74084	30.45902	-86.44882
11/21	15:46:26	10327.15430	-0.129279	1.680198	10.031007	-17.134521	19.49894	-9.02288	30.45118	-86.46383
11/21	17:52:22	10275.99609	-0.214392	0.662617	-23.837784	-13.079747	16.8501	25.40303	30.44555	-86.46219
11/23	20:17:54	50539.72266	-0.875259	2.937257	-1.390355	-17.846657	14.97424	11.77732	30.47092	-86.46930
11/23	20:13:58	64191.12500	-0.437365	1.914211	-1.476217	-21.943016	-18.7347	3.491646	30.47289	-86.47060
11/23	20:13:56	13465.21484	-0.85274	0.996877	11.848776	-16.973288	-15.8476	15.81916	30.47293	-86.47065
~~11/23~~	~~20:19:53~~	~~14664.48340~~	~~0.511883~~	~~0.708994~~	~~-19.343765~~	~~-15.121118~~	~~3.532706~~	~~26.8831~~	~~30.46931~~	~~-86.47219~~
11/23	20:20:37	22211.33984	-0.760975	0.598553	9.518229	-15.377518	19.19803	9.112197	30.46861	-86.47311

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